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THESIS

THE FORCING OF 25-KNOT WINDS AT HICKAM AND ANDERSEN AFB

by

Scott G. Smith

March 2007

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13. ABSTRACT (maximum 200 words)

This study investigates synoptic scale regimes in the forcing of 25 knot winds at Hickam and Andersen AFB. Ten years of data from January 1996 through December 2005, as well as case studies from June, July and August of 2006 were considered for this study. Days were grouped together to isolate the events of trade wind flow only and to alleviate days where trade wind flow was interrupted by synoptic scale weather events or local weather phenomena.

Of the approximately 3,650 days of observations, Hickam AFB had 258 days in which the winds gusted to or above 25 knots and 1,077 days in which the winds remained between 15 and 24 knots. Similarly, Andersen AFB had 99 days where the winds gusted to or above 25 knots and 448 days where the winds remained between 15 and 25 knots. These days were then combined in their respective lists and were compiled to create composite sea level pressure surface analyses, winds, temperature, dew point, and geopotential height for each list of days.

Upon examination of the compiled charts, identifiable climatological regimes became evident for days in which the winds gust to or above 25 knots and when the winds remained between 15 and 24 knots. The climatological average for Hickam AFB for winds gusting to or above 25 knots consisted of the subtropical high located 894 miles almost due north of Hawaii and the strength of the high at 1024 mb. The subsequent gradient across Hawaii produced an average geostrophic flow of 15 m s^{-1} across. North to South cross sections of potential temperature and winds across Hawaii indicated low static stability and analyzed winds of 7-9 m s^{-1}. The climatological average when the winds remained between 15 and 24 knots consisted of the subtropical high located much further east and with a strength of 1022 mb. This reduced the gradient across Hawaii and produced an average geostrophic flow of 11 m s^{-1}. North to South cross sections indicated stronger static stability and analyzed winds of 5-7 m s^{-1}.

Similarly for Andersen AFB, the climatological average for winds gusting to or above 25 knots consisted of a protrusion of the Siberian High due north of Guam, approximately 1050 miles away. The strength of the high was 1018 mb causing a gradient that produced a geostrophic flow of 15 m s^{-1} across Guam. North to South cross sections again revealed lower static stability and higher wind speeds associated with this regime. For the climatological average when the winds remained between 15 and 24 knots, the Siberian High had retreated to the west allowing the gradient across Guam to decrease causing the geostrophic flow to drop to 10 m s^{-1}.

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THE FORCING OF 25-KNOT WINDS AT HICKAM AND ANDERSEN AFB

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Submitted in partial fulfillment of the
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Of the approximately 3,650 days of observations, Hickam AFB had 258 days in which the winds gusted to or above 25 knots and 1,077 days in which the winds remained between 15 and 24 knots. Similarly, Andersen AFB had 99 days where the winds gusted to or above 25 knots and 448 days where the winds remained between 15 and 25 knots. These days were then combined in their respective lists and were compiled to create composite sea level pressure surface analyses, winds, temperature, dew point, and geopotential height for each list of days.

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approximately 1,050 miles away. The strength of the high was 1018 mb, causing a gradient that produced a geostrophic flow of 15 m s^{-1} across Guam. North to South cross sections again revealed lower static stability and higher wind speeds associated with this regime. For the climatological average when the winds remained between 15 and 24 knots, the Siberian High had retreated to the west, allowing the gradient across Guam to decrease and causing the geostrophic flow to drop to 10 m s^{-1}.

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ACKNOWLEDGMENTS

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Thank you to my fellow students of the class of 2007. Their dedication to see that we all exceeded during those long hours of group study will not be forgotten.

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I. INTRODUCTION

A. MOTIVATION

The ability to accurately forecast surface winds of 25 knots or greater is of significant importance to Air Force operations. When winds exceed 25 knots, aircraft maintenance, refueling operations and many other operations can be greatly impeded. For instance, aircraft maintenance troops may not be allowed to perform designated tasks while on top of an aircraft due to the chance of being blown off. Aircraft canopies may need to be secured to prevent damage and many other maintenance restrictions may need to be implemented. The restrictions are not limited to the aviation aspect, however. Engineering personnel must suspend all maintenance that requires any high level, above ground work. Therefore you can see that mission readiness can be directly affected by the forecast of 25 knots or more, making it imperative for these forecasts to be accurate.

The difficulty of correctly forecasting the onset of 25 knots or more is even more challenging in the trade wind environment of the subtropics where reaching the 25-knot threshold can be an almost daily occurrence. Hickam AFB is located on the Island of Oahu in the Hawaiian Island chain (Figure 1) and is dominated by trade wind flow for most of the year. Andersen AFB is located on the Island of Guam in the Mariana Island chain and also has trade wind flow most of the time (Figure 1). Although the trades are generally light, they can increase and cross the 25-knot threshold due to numerous situations. Large-scale weather systems such as migratory lows with trailing cold fronts or shear lines, subtropical cyclones known as Kona storms that can affect Hawaii, tropical waves as well as tropical cyclones all dictate an overall synoptic change at times when they directly affect the islands. On average, wind speeds for both locations are typically 8-11 knots, but increase to 20 knots with brisk trade wind flow as well as an increase in the afternoon due to surface heating. Both islands have very significant topography, with coastal mountains and inland plateaus that may aid in increasing the winds.

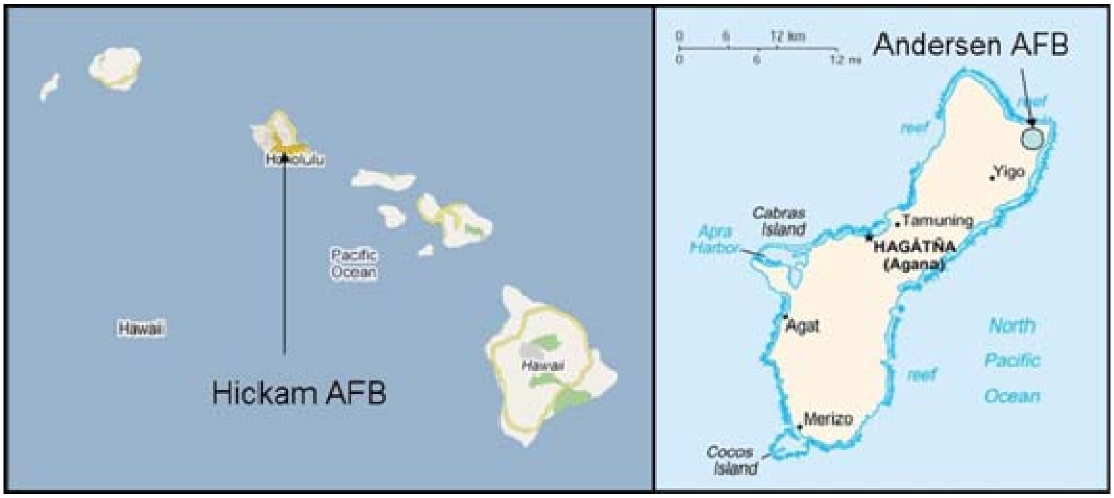

Figure 1. Hawaii and Guam (After http://maps.google.com/ and http://www.janeresture.com/guam/mapb.gif accessed 22 Jan. 07).

B. CURRENT FORECAST TECHNIQUE

With respect to Hickam, once the trade wind regime is identified, its intensity can be forecast by examining the surface pressure gradient and local island skew-Ts for gradient level wind speeds. The closer the Hawaiian Islands fall to the high center or ridge axis, the lower the wind speeds because of a maximum wind band that is found 300-500 miles south of the high/ridge axis. According to the 17 Operational Weather Squadron (OWS) Forecast Reference Notebook (FRN), when the islands fall within this maximum wind band, one should expect strong trade winds. The mean wind speed is generally 70%-80% of the gradient level winds (2000–4000 foot level); however, one must carefully watch the winds at the time of maximum heating. With scattered skies, increased heating of the surface will promote further mixing causing wind gusts that may reach as much as 100% of the gradient level winds (17OWS Hawaii FRN).

According to the FRN for Andersen AFB, most incidents of 25 knot winds occur during the dry season (Dec-Jun) due to the gradient level increase of the northeasterly trade winds by a shear line or approaching tropical wave (17OWS Guam FRN). Guam forecasters continually monitor RADAR to determine the presence of these events as well as any thunderstorm activity that may be occurring. Most high wind events occurring in the wet season (Jul-Nov), are the result of strong convection. In forecasting the surface

winds on a day-to-day basis, the forecaster uses gradient wind information. The forecasted wind speeds are 70% of the winds at 3000 feet and the highest wind gust expected is 2–4 knots above the 3000 foot winds (17OWS Guam FRN). Therefore the determination of crossing the 25-knot wind threshold, in the absence of other weather phenomena, entirely depends on how strong the winds are at 3000 feet.

C. STATEMENT OF THE PROBLEM

A Wind Advisory is issued any time the winds are expected to reach or exceed 25 knots. Once this advisory is issued, many installation facilities must be notified of its issuance in order for the respective operations to be adjusted accordingly. Although clear rules of thumb exist in forecasting the occurrence of 25 knots or more in the trade wind environment, many advisories are issued when not needed or are not cancelled soon enough when conditions have warranted its cancellation. For instance, according to 17OWS statistics, during the month of July 2005, 30 advisories for winds exceeding 25 knots were issued. Of those 30, only 19 were actually required, although two of those were after 25 knot winds had already occurred. 11 of those 30 turned out to be false alarms. Similar statistics can be found for other months as well. The ability to locate a signal that will indicate the onset and relaxation of 25 knot winds would greatly enhance forecast accuracy allowing minimal wind interruption to maintenance and flight operations.

The purpose of this study is to:

1. Examine synoptic weather conditions occurring during and in the absence of 25-knot or greater wind events and determine the overall average conditions for both instances.
2. Examine the variability of missed forecasts and false alarms to determine the critical physical processes that produce 25 knot gusts
3. Identify the critical forecast elements necessary for 25 knot gusts that will lead to more accurate forecasts.

The period of study includes 10 years of surface observation data, January 1996 to December 2005, from Hickam and Andersen AFB. The observations were broken down

into days in which no weather or a very limited amount of weather in the morning occurred in order to isolate those events that are specifically trade wind driven. Re-analysis data for those specific days was then analyzed to determine the differences.

II. BACKGROUND

A. LOCATION OVERVIEW

Hickam Air Force Base has a rich history and is an important strategic installation in the Pacific. It is home to Headquarters Pacific Air Forces and the 15th Airlift Wing. According to the 17 Operational Weather Squadron (OWS) Forecast Reference Notebook (FRN), the installation is comprised of 2,850 acres of land and facilities valued at more than $444 million. It has also been selected to house the newest squadron of C-17 Globemaster III cargo aircraft, the most modern cargo aircraft in the Air Force fleet, dramatically increasing the dollar value of the facilities. Hickam is located on the southern side of the island bordered by Naval Station Pearl Harbor to the west and Honolulu International Airport, with which it shares runway operations, to the east (Figure 2). The location is also an alternate Space Shuttle landing site.

Figure 2. Pearl Harbor, Hickam AFB and Honolulu International Airport. (From http://maps.google.com/ accessed 14 Nov 06).

Andersen Air Force Base is located on the north east side of Guam (Figure 3) and is home to Pacific Air Forces 13th Air Force and the 36th Wing (17OWS Guam FRN). Andersen plays a vital role in maintaining U.S. presence in the Pacific and Indian Oceans and provides for a forward operating logistical center for deployments throughout the entire region. Many aircraft are deployed to Andersen throughout the year including the highly valued B2 Stealth and B1B bombers, fighter aircraft such as the F15 and F16 as well as airlift, tankers and helicopters. The airfield has dual two mile long runways and huge fuel and munitions storage facilities and plans for future growth are in the works. It is an ideal training location due to its close proximity to a naval bombing range near the island of Farallon De Medinilla. Five miles to the northwest of Andersen is a runway complex called Northwest Field and has become an expeditionary combat support training area (Air Force Print News Today 2006). Growth at Andersen will see facilities for the new F-22A Raptor and Global Hawk unmanned aerial vehicle and combined with a regular rotation of other aircraft, the installation will almost definitely see an increase in the population requiring more base housing and further infrastructure (Air Force Print News Today 2006).

Figure 3. The island of Guam. Andersen AFB is located on the Northeast side. (From 17OWS Guam FRN).

B. THE NORTHEAST TRADE WINDS

The northeast trade winds are found north of the equator and on the southern periphery of the eastern pacific subtropical high. Over the tropical Pacific, the Walker and Hadley circulations are the resultant circulation patterns in response to the redistribution of warm air from the tropics towards the poles and vice versa. (Kodama and Businger 1998). The Walker circulation is the east/west flow and has an ascending branch in the western Pacific and a descending branch in the eastern Pacific. The Hadley circulation is the north/south circulation and has an ascending branch near the equator and a descending branch near 30° N/S. Subsidence associated with these circulations creates a semi-permanent high-pressure system in the subtropical eastern Pacific. The

persistent anticyclonic flow around the high allows northeasterly flow to dominate the lower latitudes of the Northern Hemisphere creating the northeast trade winds. The location and intensity of the High vary from day to day and even season to season. It is these variations that present the problem of correctly forecasting the strength of the trade winds at both Hickam and Andersen AFB.

Due to the semi-permanent nature of the subtropical high, subsidence over the islands of Hawaii and Guam is an everyday occurrence, creating an inversion known as the trade wind inversion. The persistence of this inversion provides a significant cap to the atmosphere, hindering cumulus development except where orographic forcing is present. The mean height of the inversion is 6400 feet and has been observed as low as 3500 feet (17OWS Hawaii FRN).

The height of the trade wind inversion is determined by atmospheric conditions below and above it. Low-level turbulence due to surface heating acts to raise the inversion. Strong subsidence above the inversion acts to dry the air and lower the inversion height. According to the 17OWS FRN, a lower and stronger inversion is characteristic of strong trade wind flow. This is either the result of stronger subsidence associated with the intensification of the sub tropical high, or the location variation of the high itself. This study will examine how the synoptic patterns and trade wind inversion relate to produce 25 knot wind gusts.

As stated previously, due to the changing seasons, the subtropical high has an annual North/South migration in response to the location of intense surface heating (Figures 4 and 5). In January, the average center of the high is near 30°N, 130°W, with the ridge axis extending southwestward to near 25°N. In July, the high has moved further to the north with the center located near 35°N, 155°W and the ridge axis extending between 30°N and 35°N (Kodama and Businger 1998). Depending on the time of year, the islands of Hawaii and Guam are directly influenced by the trade winds.

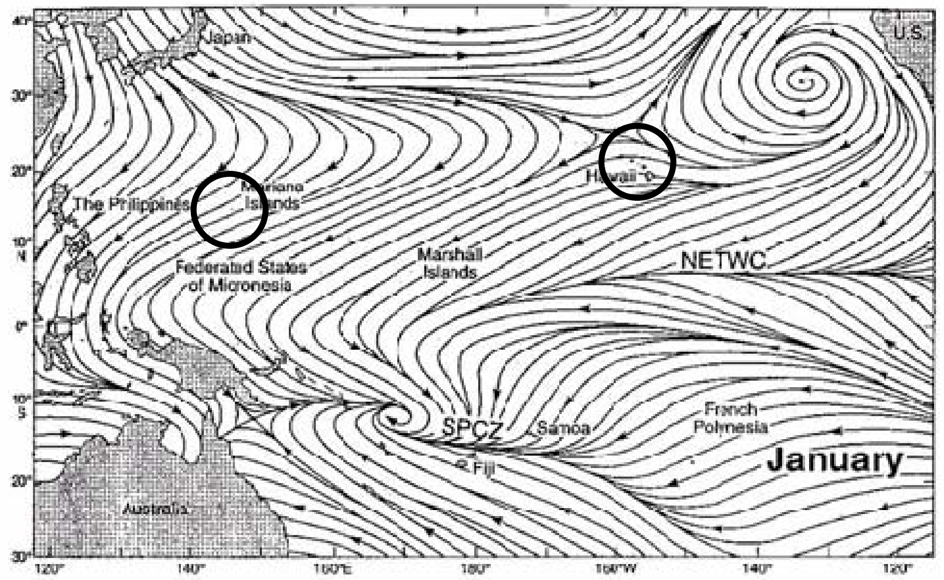

Figure 4. Streamlines of average surface winds over the Pacific in January. (After Elsberry, chapter 1)

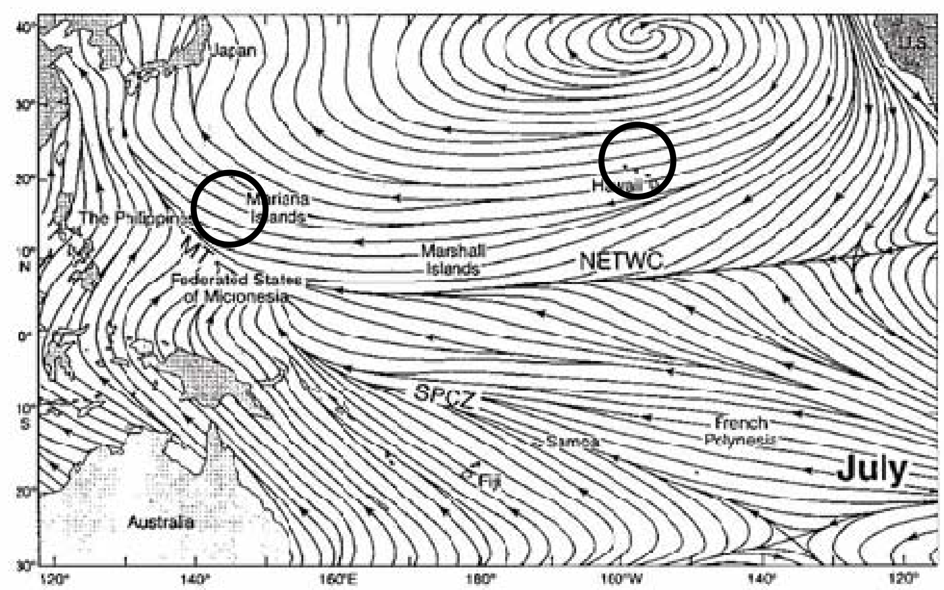

Figure 5. Streamlines of average surface winds over the Pacific in July. (After Elsberry, chapter 1)

This migration of the subtropical high is directly responsible for the frequency of trade wind flow over the islands. In the summer, since the center of the high is further north, it acts as a shield to block any mid-latitude cyclones from moving further south,

thus disrupting trade wind flow over Hawaii. With its movement toward the south in the winter, mid-latitude cyclones are able to progress further south and disrupt the flow. Thus, the Hawaiian Islands have trade wind flow approximately 70% of the year with summer months being the most at 90% and winter months the least with 50%; however, in Guam, the highest frequency of trade winds (90%) occurs in the winter months and the lowest (40%) in the summer months (Kodama and Businger 1998). With the southward shift of the high in winter, the gradient increases over Guam, causing winds of 10-20 knots with possible gusts from 35-40 knots (17OWS Guam FRN).

The summer minimum in trade wind frequency for Guam is due to a monsoon trough that moves over and north of the Marianas (Kodama and Businger 1998). The convergence of the cross-equatorial flow, Inter-Tropical Convergence Zone (ITCZ), and its location varies with the seasons due to surface heating. In figures 4 and 5 above, the ITCZ is shown as the NETWC or Near Equatorial Trade Wind Convergence zone and the difference is simply due to disagreements on the overall definition of the zone. The northern most distance the ITCZ will move and retain its characteristics is about 8° from the equator (figure 6). Once this area moves further than approximately 8° to 10° away from the equator, the southeast trades begin to feel the effects of Coriolis and become south westerlies (Figure 7). When this occurs, the area is known as a monsoon trough and since Guam is located at roughly 13°N, in the summer months the monsoon trough traverses Guam and disrupts the normal trade wind flow.

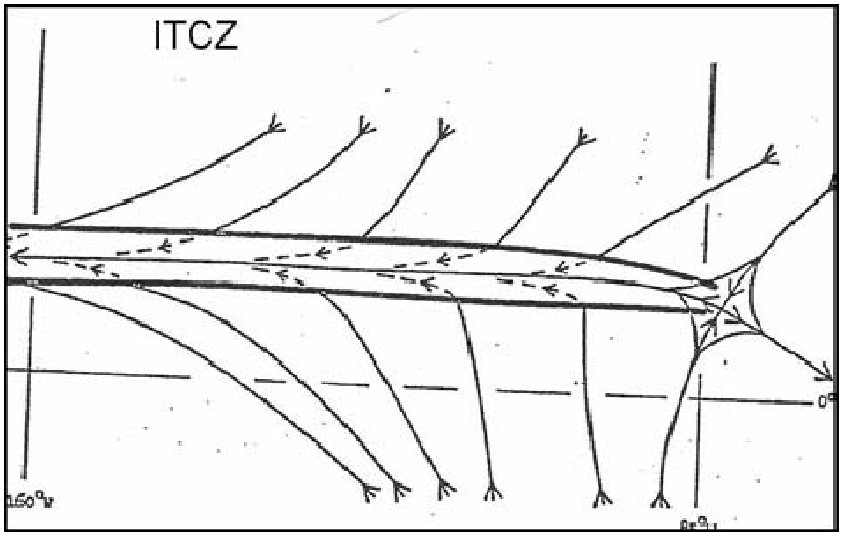

Figure 6. Convergence Zone of northeast trades and southeast trades creating an Inter-tropical Convergence Zone (ITCZ). (From Elsberry, Chapter 1)

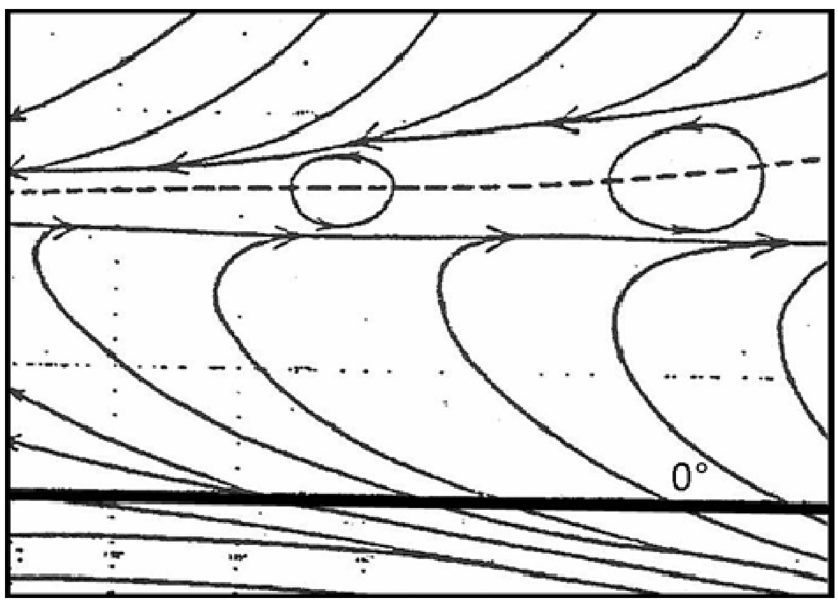

Figure 7. Convergence zone where Coriolis has had time to deflect the southeast flow to the right creating westerlies. The resultant trough of low pressure induces a cyclonic spin and is known as a monsoon trough. (After Elsberry, Chapter 1)

C. MODIFYING EFFECTS

The strength of the trade wind flow across the islands is dependent on the strength of the subtropical high and its location. A weak subtropical high or its position too close or too far from the islands can allow a sea breeze to develop causing onshore winds during the daytime hours and drainage winds at night from nearby mountains. Seasonal

variability of the subtropical high location will allow migratory systems to disrupt the trade wind flow as well. The movement and strength of the high also influences the characteristics of the trade wind flow. The 17OWS notes they can be classified into three distinct trade wind regimes called the “Dry” trades, “Wet” trades and “Strong” trades. Dry and wet trades are more of a concern for precipitation forecasting, but the strong classification ties directly to intensity of the subtropical high and can be a precursor for the issuance of 25-knot wind advisories. Strong trades are associated with a strong subtropical high or migratory high typically above 1034 mb (17OWS Hawaii FRN). With a strong high present, the gradient between the high and lower pressure near the equator will tighten, increasing trade wind flow to 25-35 knots.

The question that arises then is whether a stronger high simply equates to stronger winds over the islands, as is suggested by previous studies. If the location of the high allows either location to fall outside of the 300-500 mile zone in which strong trades are present, then crossing the 25-knot threshold should not be a concern; however, observations have shown wind gusts above 25 knots even though the islands fall outside of this zone. The relationship between large scale pressure changes and stability as well as diurnal affect that force changes in the static stability of the boundary layer may both contribute to high wind gusts. This study will examine these relationships to produce more refined criteria in order to forecast wind gusts more accurately.

D. HICKAM AFB GEOGRAPHY AND CLIMATOLOGY

1. Area Geography

As previously stated, Hickam AFB is located on the southern edge of the Hawaiian island of Oahu adjacent to Pearl Harbor Naval Station (Figures 1 and 10). Oahu is the third largest of the islands with 604 square miles of land area. From the southeastern tip near Makapuu Point to the most northwestern point of Kaena Point, Oahu measures only 39 nautical miles (NM) (Figure 10) and 26 NM from Barbers Point on the south side to Kahuku Point to the north.

There are two prominent mountain ranges on Oahu. The Koolau Range lies nearly along the entire northeast coast and is perpendicular to the prevailing trade winds. The southern tip of the range from Makapuu Point to Kaneohe Bay is a shear, rocky cliff

(Figure 8) on the ocean side and is nearly 2,000 feet high (17OWS Hawaii FRN). Moving further northward, the range transitions into steep, rugged slopes gradually decreasing in elevation as it gets closer to the sea. The entire range is very jagged with deep gorges and valleys on its inland side. The Koolau Range's highest elevation of 3,150 feet is along the southeastern shore and is approximately 16 miles northeast of Hickam AFB (17OWS Hawaii FRN).

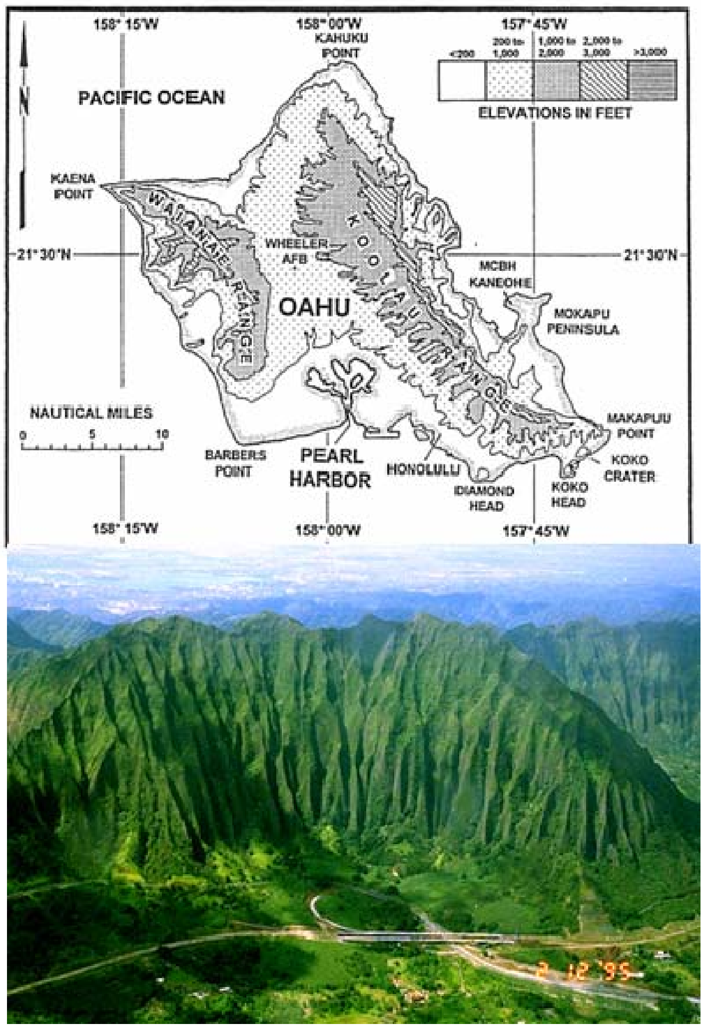

Figure 8. Topographical map of Oahu with a picture of the windward side. (From 17OWS Hawaii FRN)

The Waianae mountain range parallels the western coast from Kaena Point to just north of Barbers Point. There are numerous peaks above 3,000 feet with Mount Kaala, at 4,046 feet, the highest point on Oahu and 12 miles north to northwest of Hickam (17OWS Hawaii FRN).

Between the two ranges, is an extensive plain from Pearl Harbor to an area known as Haleiwa. It rises to a height of 1,000 feet at Wahiawa with rolling hills near the Koolau Range. Most of the area is agricultural and is primarily made up of sugarcane and pineapple (17OWS Hawaii FRN). With the exception of a few small reservoirs, there is very little inland water on Oahu (17OWS Hawaii FRN).

The local topography in the vicinity of Hickam is relatively flat but begins a gradual upslope towards the Koolau Mountains not far from the base resulting in a drainage wind at night in the absence of normal trade wind flow. The prevailing trade winds flow across the Koolaus causing showers in the mountains with drier downslope flow as you progress towards Hickam. The city of Honolulu is located 17 miles to the east of Hickam and, due to urban development; there is very little vegetation around the installation (17OWS Hawaii FRN).

2. Hickam Climatology

The prevailing wind direction for Hickam AFB varies from the northeast to east during all months of the year. Average winds speeds are 7-10 knots with wind gusts over 25 knots comprising just a small percentage of the total. The location and strength of the semi-permanent Pacific High dictates the strength of the trades, and whether or not other migratory systems will affect the islands. Other effects are due to migratory mid-latitude cyclones, frontal systems, or shear lines, and the overall island topography. Figure 9 shows the overall annual average winds in percentage for Hickam AFB. The percentages are labeled on the North axis and are computed by looking at the specified range of winds and subtracting the remaining lesser ranges. The 22-27 knot range begins near 35% and ends near 37% roughly meaning that the overall percentage of these winds occurring is about 2%. Our interest in winds greater than 25 knots indicates the percentage of these winds occurring is even less than that.

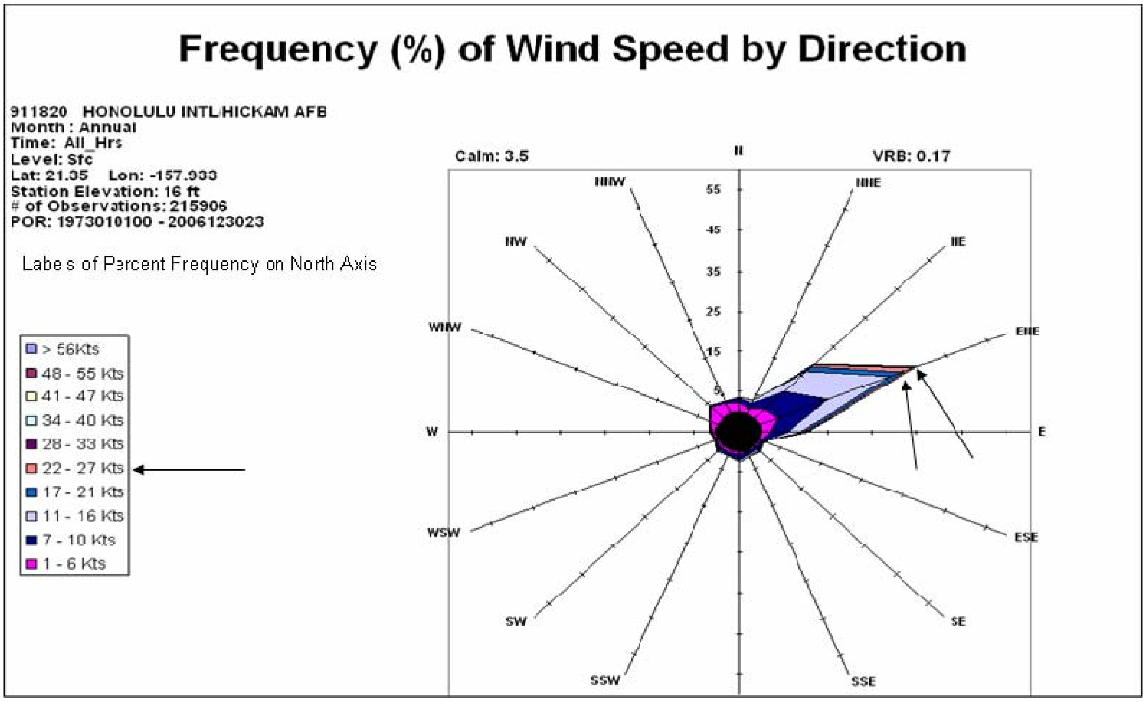

Figure 9. Hickam AFB annual wind summary (from AFCCC).

E. ANDERSEN AFB GEOGRAPHY AND CLIMATOLOGY

1. Area Geography

The island of Guam is made up of three main topographical regions. These are the northern plateau in which Andersen AFB is located, the central lowlands, and southern mountain region. Guam is located very near the equator at 13.35' North latitude and 144.56' East longitude and so the weather there is greatly influenced by this and the surrounding warm waters of the equatorial Pacific Ocean. The island is only 30 NM long and varies in width from 5 to 10 miles encompassing an area of 255 square miles (17OWS Guam FRN). Steep cliffs that average 300-600 feet lay along the entire northeastern shore line (Figures 10 and 11). Mount Santa Rosa is 2 NM south of the base and has an elevation of 820 feet. The inner plateau region is generally forested; however, there are no streams or rivers due to the porous coral subsoil. The southern half of the island is more mountainous but does not have the steep cliffs that face the ocean. Mount Lamlam is 19 NM southwest of Andersen and rises to a height of 1,334 feet.

Figure 10. Northeastern shore of Guam (left) with view of the approach end of the runways (right) (From 17OWS Guam FRN).

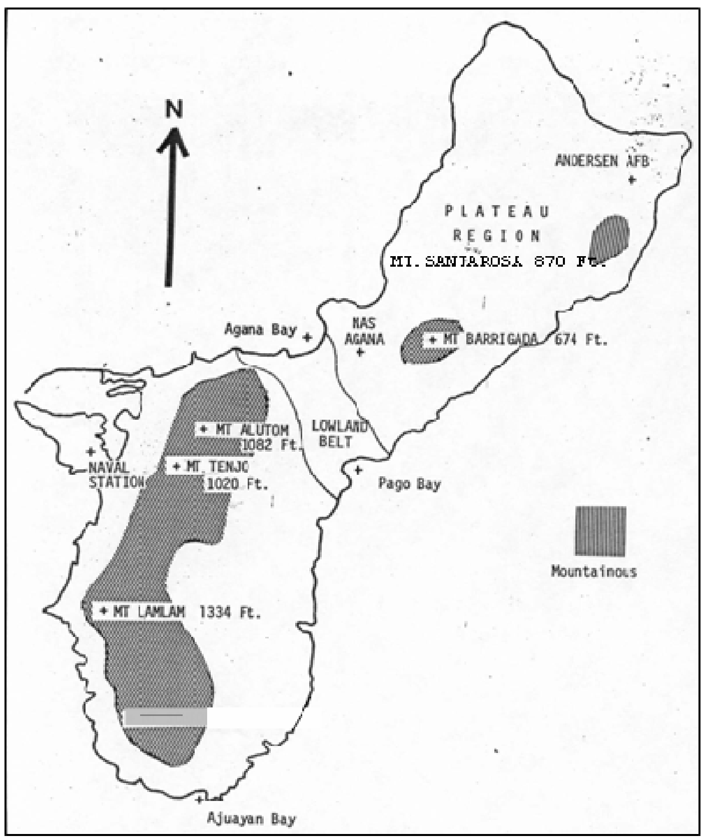

Figure 11. Topographical map of the island of Guam (From 17OWS Guam FRN)

2. Andersen Climatology

Guam forecasters have determined that climatology and persistence are very useful tools when forecasting for Andersen AFB (17OWS Guam FRN). Due to its close proximity to the equator, Guam is directly affected by the seasonal variability of the subtropical ridge and ITCZ. In the summer, the ITCZ shifts further northward into the Northern Hemisphere because of the increased solar insolation north of the equator. This results in the subtropical ridge axis moving further northward as well allowing more humid, tropical air to affect the island and interrupt the trade wind flow. In the winter months, the ITCZ returns to near the equator allowing the subtropical ridge to shift further southward as well. This brings drier air and the return of the trade winds back to the island resulting in the dry trade regime. The prevailing direction of the winds are from the east northeast January through March and are more easterly the remainder of the year. The mean wind speed from the prevailing direction is from a high of 12 knots in January and February to a low of 7 knots in August and September. Figure 12 shows the overall percentages of wind direction and speed for Andersen AFB.

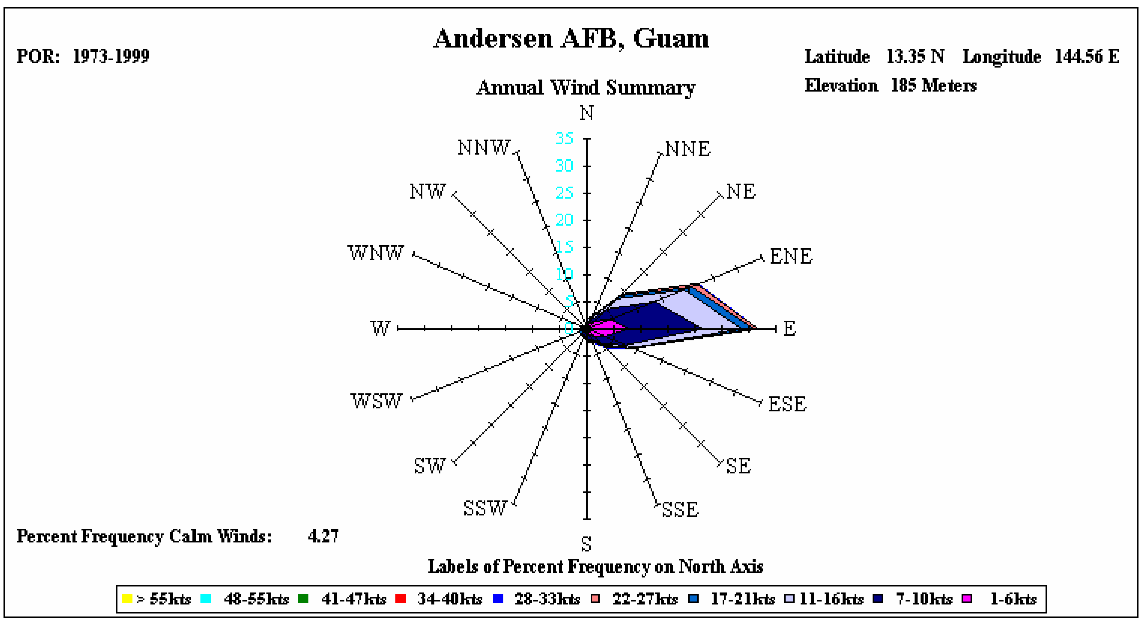

Figure 12. Andersen AFB Annual Wind Summary (From 17OWS Guam FRN)

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III DATA AND METHODOLOGY

Ten years of data from January 1996 through December 2005, as well as data from June, July and August of 2006 were considered for this study. The three months in 2006 were needed to review case studies from the 17OWS. Days were grouped together as such to isolate the events of trade wind flow only and to alleviate days where trade wind flow was interrupted by synoptic scale weather events. The following sections describe the methods used for the gathering of data and procedures for grouping days.

A. DATA

1. Surface Observations

Surface observations for Andersen AFB and Honolulu International Airport were acquired via a Support Assistance Request (SAR) from the Air Force Combat Climatology Center (AFCCC) in Asheville, NC. June, July, and August 2006 were downloaded directly from the AFCCC website. AFCCC provided hourly reports of surface weather phenomena in column format using Microsoft Excel as well as a comma delimited text file for the 2006 data. Wind direction, speed (knots), gusts (knots), and pressure (Ins Hg) were used in the study.

The National Weather Service Honolulu operates and maintains the Automated Surface Observing System (ASOS) located on the airfield near symbol # 2 on figure 13. The Federal Aviation Administration (FAA) is responsible for taking and disseminating weather observations for Honolulu International with which Hickam shares space. The FAA uses the ASOS to take Meteorological Aviation Routine (METAR), special (SPECI), and local observations in accordance with federal regulations (17OWS Hawaii FRN). A certified contract observer augments the automated system when required.

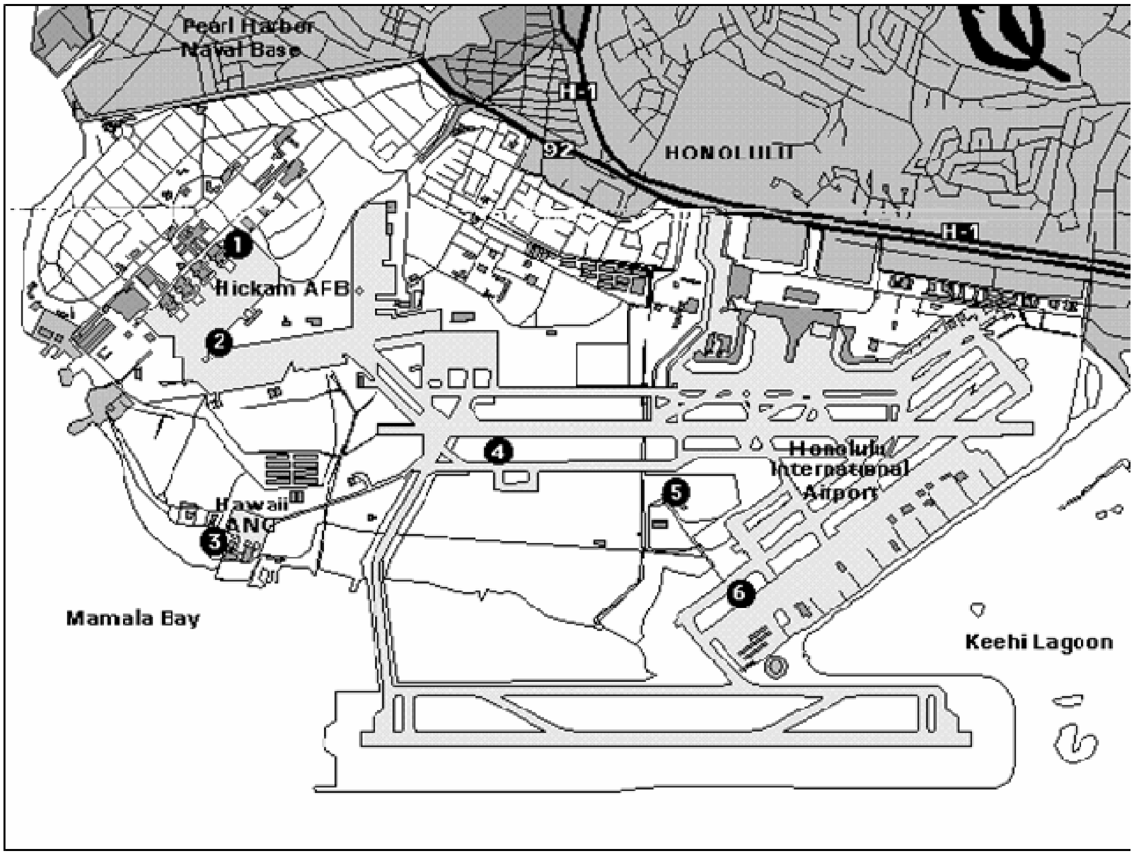

Figure 13. Diagram of Honolulu International Airport and Hickam AFB showing equipment locations with the airfield's primary wind sensor located at point 2 and the ASOS site located at 4 (After 17OWS Hawaii FRN).

The Andersen AFB Combat Weather Team (CWT) is located on the southern side of the runway complex and is responsible for taking and disseminating weather observations. The CWT uses the variety of meteorological sensors (Figure 14) to take METAR, SPECI, and local observations in accordance with Air Force regulations.

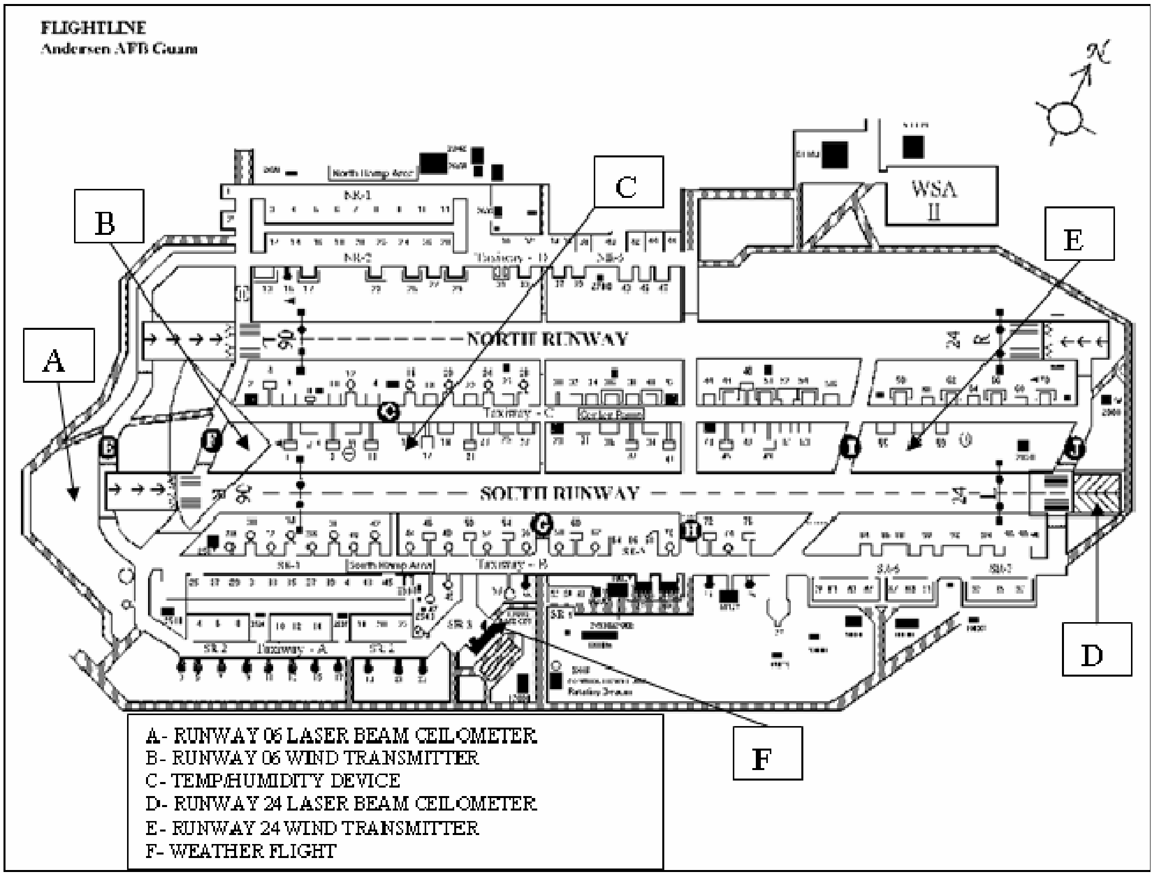

Figure 14. Diagram of Andersen AFB with location of weather sensors used for observing (after 17OWS Guam FRN).

2. Radiosonde Data

Radiosonde data for the research period were available to download from NOAA's Earth Systems Research Laboratory Global Systems Division website (http://raob.fsl.noaa.gov). World Meteorological Organization (WMO) station identifiers were used to load the appropriate radiosonde data in text and graphic form for analysis. These were 91165, Lihue Airport, Kauai Island (Figure 15), to best represent Hickam AFB and 91212, Agana National Weather Service office, Guam (Figure 16). These upper air data were used to analyze stability and wind profiles for case studies that did not resemble overall averages of certain days to be explained later.

Figure 15. Location of radiosonde site with respect to Hickam AFB. (After http://maps.google.com/).

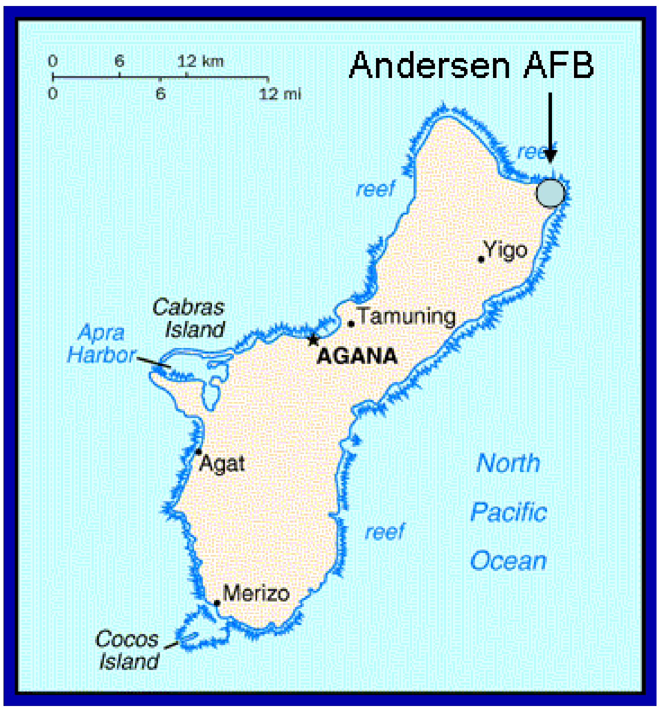

Figure 16. Location of Agana, Guam in respect to Andersen AFB. (After http://www.janeresture.com/guam/mapb.gif).

3. NCEP/NCAR Surface Reanalysis Data

In order to compile and average days with similar criteria, NCEP/NCAR reanalysis data were interpolated to a horizontal grid covering the entire North Pacific Ocean (Figure 17). NCEP/NCAR reanalysis of zonal and meridional wind components, air temperature, dew point, mean sea level pressure, and geopotential height were interpolated from a 2.5 degree Lat/Lon grid to a 120 km Lambert conformal grid. Reanalysis variables were available every six hours at 00, 06, 12, and 18 UTC and in standard GRIB format from the NPS Department of Meteorology.

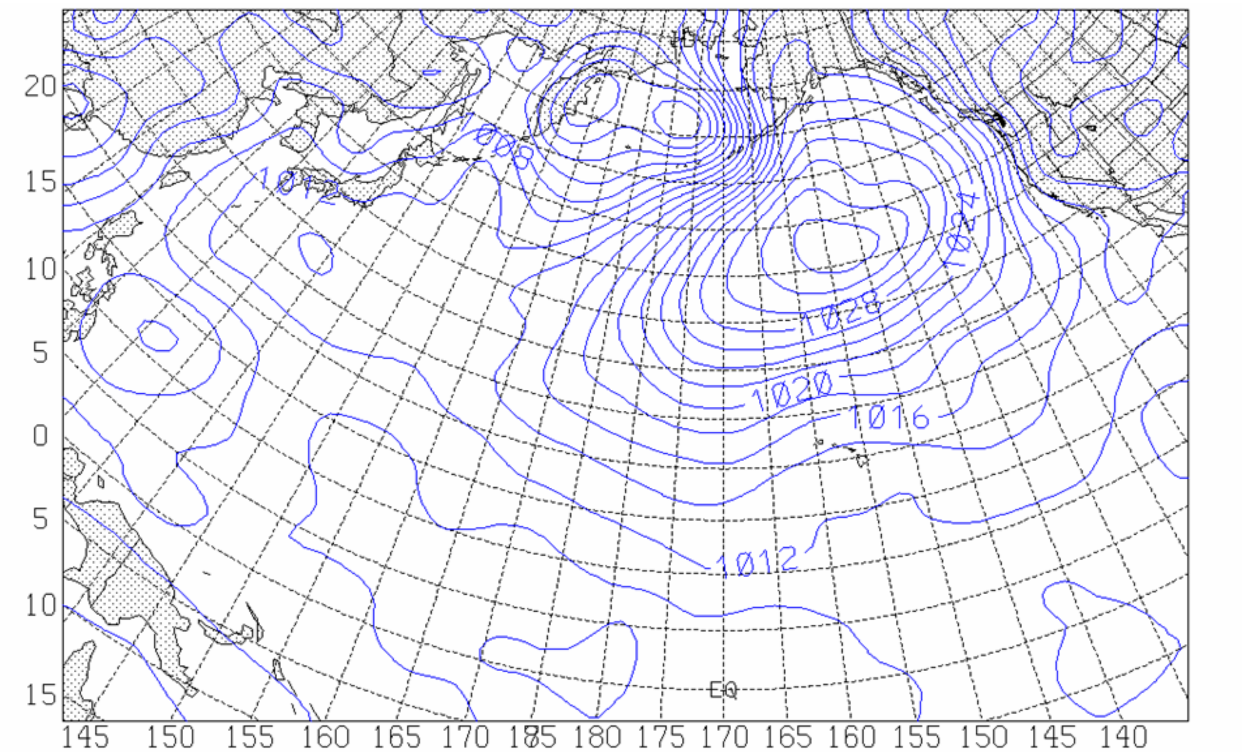

Figure 17. Example of reanalysis grid covering the North Pacific Ocean.

B. METHODOLOGY

1. Generation of Undisturbed Days with Wind Requirements

The first step in this study was to compile a list of days that were not disturbed by large-scale synoptic weather systems or local events, such as afternoon thunderstorms, that would interrupt trade wind flow. FORTRAN code was developed to analyze the entire observation set from both locations and reject days in which the observation

indicated any type of rain occurring (Nuss 2006). This code also included wind criteria that would separate those days into categories based on desired wind speeds. Once complete, the code generated a list of days from the observation set that were uninterrupted by rain and met the desired wind requirements. These lists were then reviewed to ensure those days fell under large scale synoptic high pressure, the norm for which trade winds occur. For Hickam AFB, of the roughly 3,650 days of observations, there were 258 days in which, at least one observation, indicated the winds had gusted at or above 25 knots and another list of 1,077 days in which the winds were between 15 and 24 knots. Similarly for Andersen AFB, 99 days were found to have wind gusts at or above 25 knots and 448 days in which the winds were between 15 and 24 knots.

The code listed a day as YYMMDD and is the 24 hour period beginning at 12 UTC the previous day. A day listed as 960218 would be 18 February 1996 and consists of the 24 hour period from 12 UTC 17 February to 11 UTC 18 February. The observations for the day only included synoptic observations, METAR, that occurred on the hour. No SPECI observations were included in order to treat all days equally with exactly 24 observations.

2. Compositing

Each list represents days where conditions were favorable for certain events to occur. It was necessary to generate a list where conditions allowed for the 25-knot threshold to be crossed as well as a list that included days that did not quite reach the threshold. Now these separate lists were compiled using a program called RUN-AVERAGE (Nuss 2006). This program takes the designated input list, from the previous code and with its accompanying gridded data, and computes the mean of the specified field at each grid point, resulting in a composite field over the research area that can be displayed. The output file name must be in date format, YYMMDD, but does not represent a true date as it is a composite of many dates. The output file names for Hawaii are 080101 for 25 knots or greater and 080102 for wind gusts of 15-24 knots. For Guam, 090101 and 090202 were used likewise. When displaying any chart, the filename will be listed in date format and should not be confused with an actual date in the year 2008 or 2009. Composite sea level pressure surface analyses, winds, temperature, dew point, and

geopotential height were produced for each list creating identifiable regimes for greater than or less than 25 knot wind occurrences.

3. VISUAL

VISUAL (Nuss 2006) is a FORTRAN program developed to display a wide variety of meteorological datasets. The program is based on NCAR graphics and XGKS graphical software for plotting. Options within the program allow the user to develop a wide variety of computations and work with the plot to generate the desired output (Nuss and Drake VISUAL). VISUAL affords users a simple but powerful diagnostic tool to examine a variety of data with minimal effort.

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IV. RESULTS

This chapter presents the results from the composite surface analysis charts for the identified climatological regimes of greater than or less than 25 knots for both locations. Upon examination of the observations for Hickam, it was discovered that the vast majority of stronger wind gusts occurred within a few hours of 00 UTC. For Guam, wind gusts above 25 knots occurred at all hours but the majority occurred between 00 and 06 UTC, 1000-1600 local time. This suggests a favorable diurnal condition exists for both locations. Once RUN-AVERAGE was executed for each list, VISUAL was used to load the desired field either at 00, 06, 12, or 18 UTC for analysis of each regime. Two distinctly different sea level pressure charts arose from the averaging for Hawaii; however the differences for Guam are not as obvious, but are still evident. In analyzing the differences, cases in which the 25-knot threshold was crossed or when it was not crossed were compared with the overall climatological averages for each case. Those that more closely matched the opposite case i.e. the case resembled 25-knot or greater climatology but the winds never reached 25 knots, were then analyzed in further detail to understand why. The following sections will present the average cases and then compare similar and dissimilar events.

A. HAWAII AVERAGES

1. Climatological Average Conditions for 25-Knot Winds

A composite sea level pressure chart based on the list of days with winds of 25 knots or greater was created for Hawaii. Figure 18 shows what the average sea level pressure pattern at 00 UTC over the Pacific looks like on those days in which the winds at Hickam gusted to or above 25 knots. As can be seen from the chart, the high pressure center is located due north of Hawaii, between 35° and 40°N and 155° to 160°W, which is approximately 894 miles away. This places the islands outside of the 300-500 mile wide max wind band as depicted by the box on figure 18. The strength of the subtropical eastern North Pacific high averages just over 1024 mb throughout the entire day with little change diurnally. The only noticeable changes between the early morning and afternoon hours were the overall size of the high and the gradient across Hawaii (not

shown). At 1800 UTC, 0800 local time, Oahu is located between the 1020 and 1018 mb contour and the 1024 mb contour is much broader than in figure 18. By 00 UTC, 1400 local, the 1018 mb contour has moved north of Oahu as the gradient tightens across the islands.

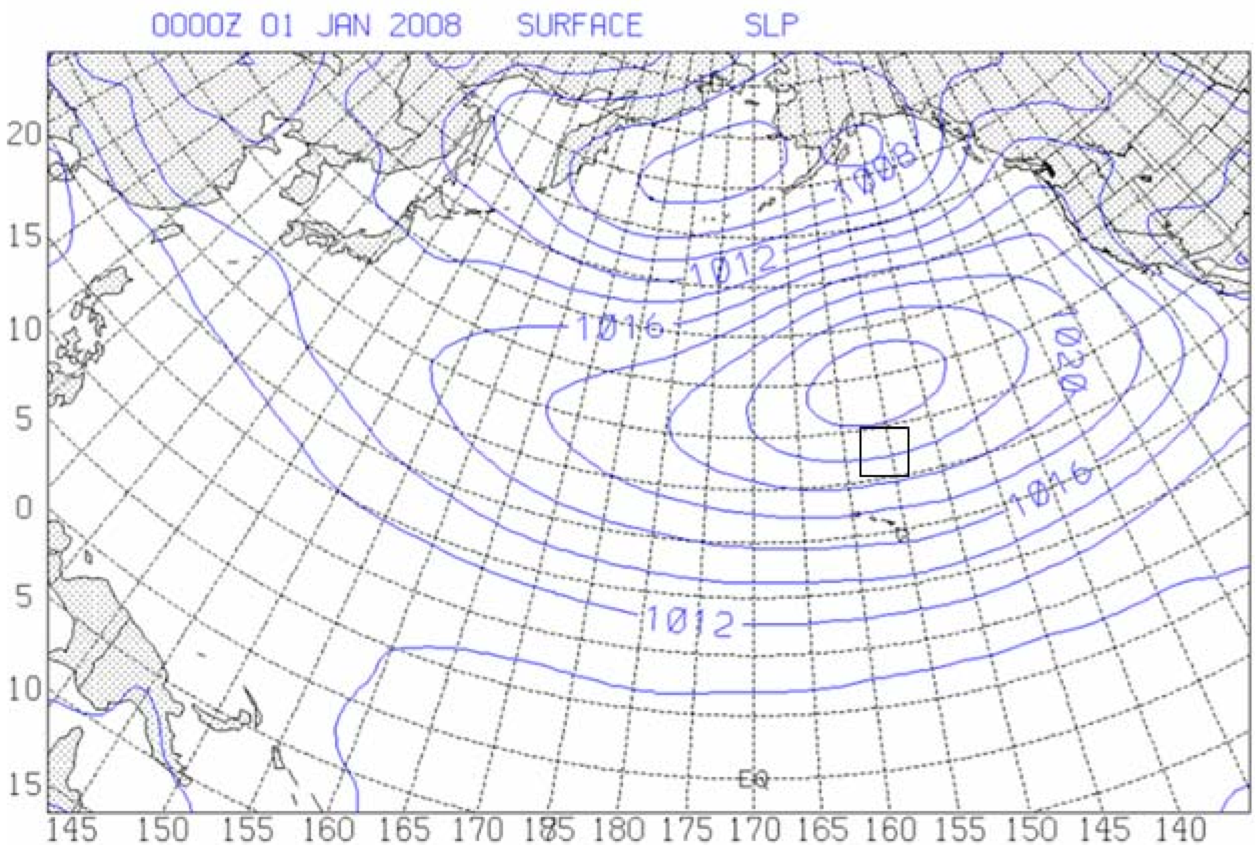

Figure 18. Average sea level pressure pattern (2mb increments) over the Pacific at 00 UTC for days 25 knots or greater

Figure 19 is a North to South cross section view of the lower troposphere from roughly 35°N on the left to 15°N on the right and over the island of Oahu and Hickam AFB (approximately 158° W) at 00 UTC with the vertical line denoting the approximate location of Hickam. The plot displays potential temperature contours, isentropes, in Kelvin and the analyzed isotachs in meters per second. Vertical level in millibars (mb) is listed on the left axis. Although not unstable, relatively low static stability is found in the layer below about 925 mb indicated by the widely spaced and nearly vertical isentropes. The more horizontal isentropes above 925 mb indicate a more stable atmosphere above and the approximate location of the trade wind inversion. The isotachs indicate that the

average analyzed winds near Hawaii on these days are between 7 and 9 m s^{-1}. The geostrophic flow (not shown) across Hawaii is 14 m s^{-1} indicating that the gradient is strong enough to produce wind gusts of greater than 25 knots. Upon examination of the other times through the day (cross sections not shown), only small (i.e., 1 m s^{-1}) changes in the analyzed winds occur, but a noticeable change in stability is observed diurnally. The isentropes in the 925-1000 mb layer are more horizontal in the morning hours and become more vertical as 00 UTC approaches. This decrease in static stability is consistent with the max wind gusts occurring around 00 UTC when vertical mixing would be favored.

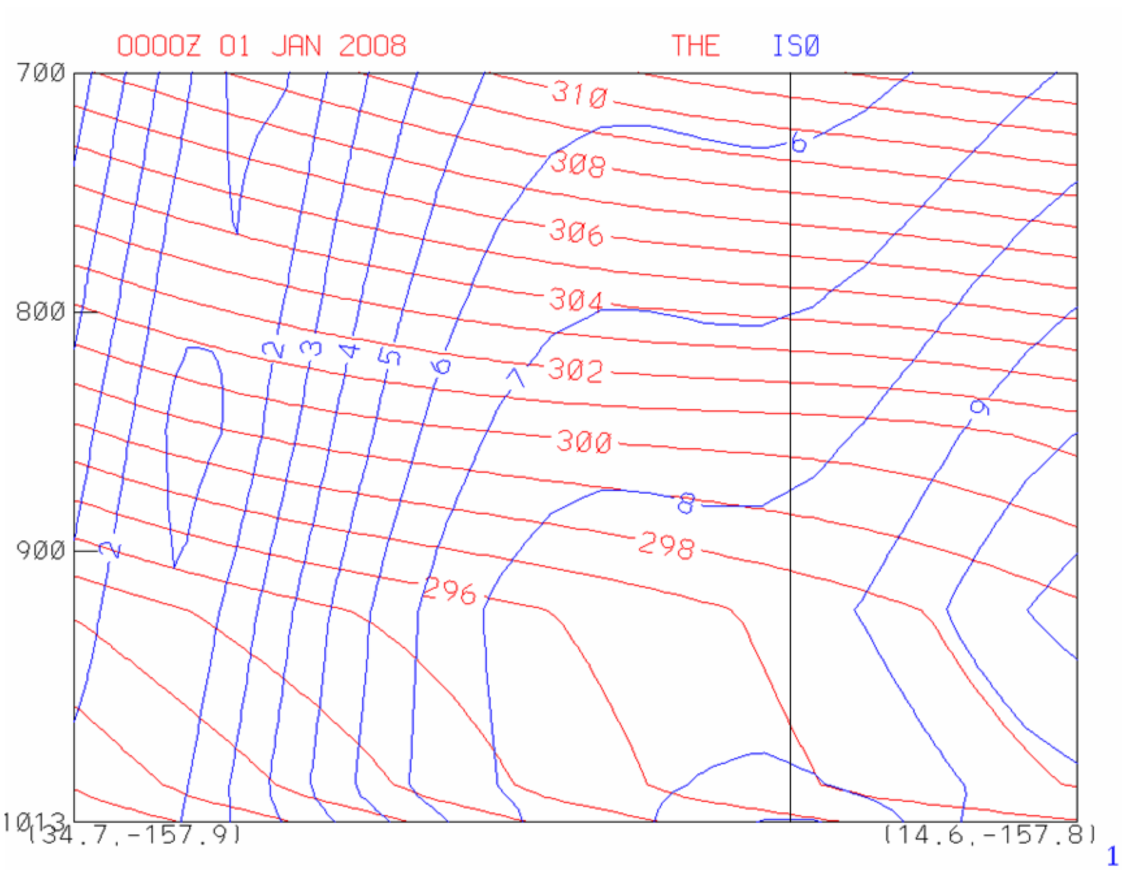

Figure 19. Cross sectional view of the average lower atmospheric conditions at 00 UTC for days with 25 knot or greater winds

2. Climatological Average Conditions for Winds 15–24 Knots

Figure 20 displays the average sea level pressure pattern at 00 UTC over the Pacific for those days that did not cross the 25-knot threshold and is labeled as 02 January

2008 for reference. This pattern is remarkably different than that of the 25-knot case. The average strength of the pressure gradient is less than the 25-knot average with the high pressure center at just over 1020 mb. Plots for the other hours showed no noticeable fluctuations in the strength of the high throughout the day. Its location is much further east, between 150°W and 145°W placing Hawaii well outside of the suggested max wind band. Hawaii remains under the northeast trade winds and roughly between the same pressure contours as the 25-knot case however the pressure gradient is weaker than for the 25-knot days.

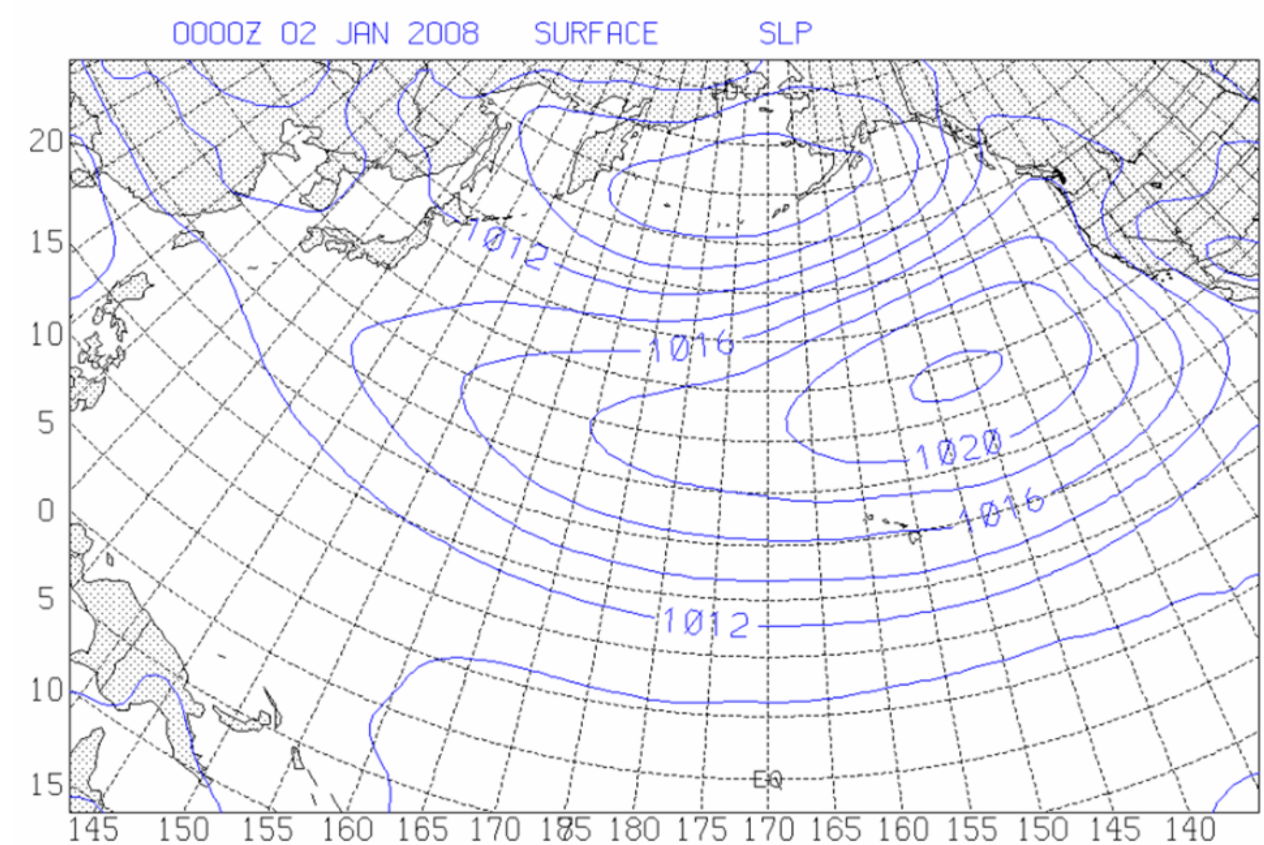

Figure 20. Average sea level pressure pattern at 00 UTC over the Pacific for days 15-24 knots

Figure 21 is a North to South cross section of the lower troposphere over the same location as the previous cross section in the 25-knot case. The structure is similar to the 25-knot case however there are subtle differences. The isentropes are less vertical indicating a bit more static stability than in the 25-knot case. Examining the other times

showed some diurnal changes in stability with conditions even more stable in the morning hours, especially when compared to 25-knot climatology. Isotachs are now between 5 and 7 m s^{-1} with the geostrophic flow (not shown) 11 m s^{-1}. Thus, even with increased vertical mixing in the afternoon, the large scale winds at the top of the boundary layer are well below the 25-knot threshold.

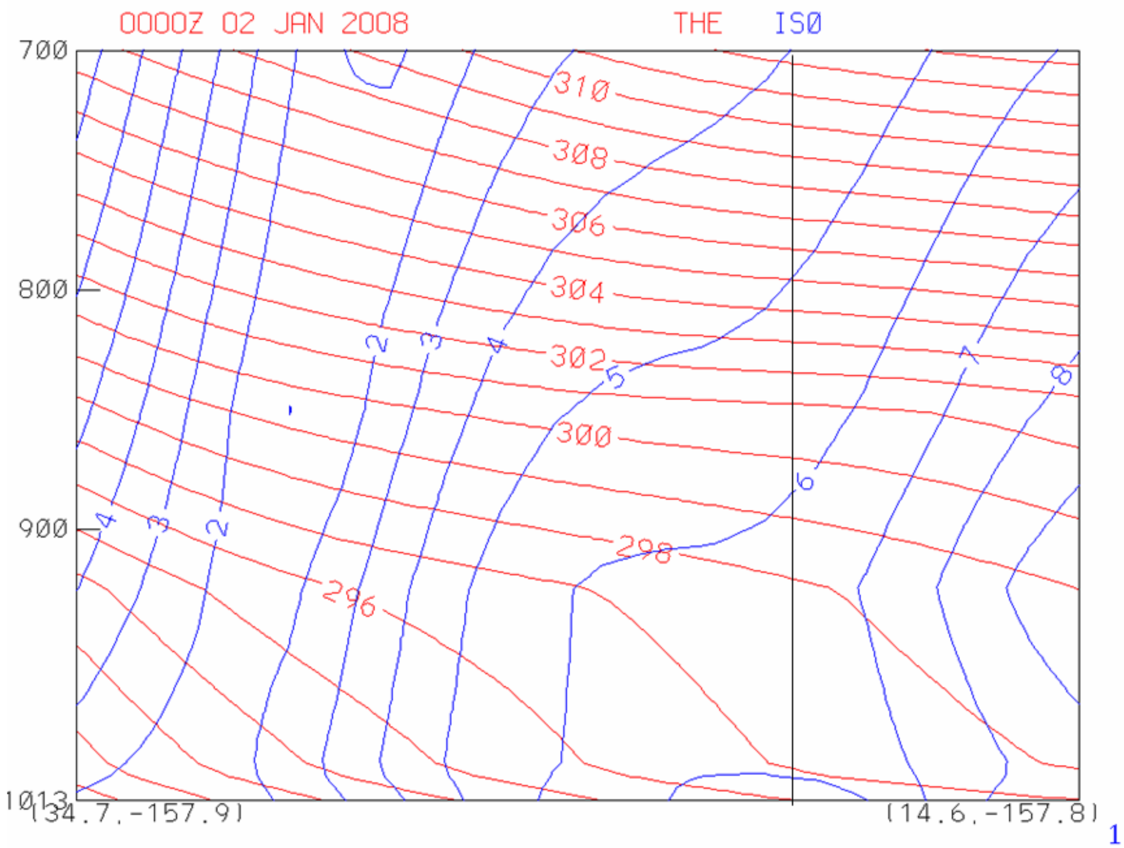

Figure 21. Cross sectional view of the average lower atmospheric conditions for days 15-24 knots

B. GUAM AVERAGES

1. Climatological Average Conditions for 25-Knot Winds

The output data file name for these cases was labeled as 01 January 2009 to distinguish it from the Hawaii averages and actual days. Figure 22 shows the average sea level pressure pattern at 00 UTC over the western Pacific for the 25-knots or greater wind days. Notice the extension of the Siberian High extending into the western Pacific approximately 1,050 miles north of Guam, placing Guam outside of the 300-500 mile

wide max wind band as indicated by the box on Figure 22. Examination of all four analyses times showed a diurnal cycle associated with the high pressure center north of Guam in that at 18 UTC it is at its strongest at 1018 mb. The high gradually retreats to the west and has decreased to 1016 mb north of Guam by 06 UTC, and then begins to expand east again, reaching its strongest point near 18 UTC. The eastern Pacific sub tropical high is east of Hawaii, resembling that of the 15-24 knot cases for Hickam AFB, and a large area of low pressure of approximately less than 1000 mb is centered near the Aleutian Islands. The average location of the 1012 mb contour is almost directly over Guam which is indicated by the circle on Figure 22.

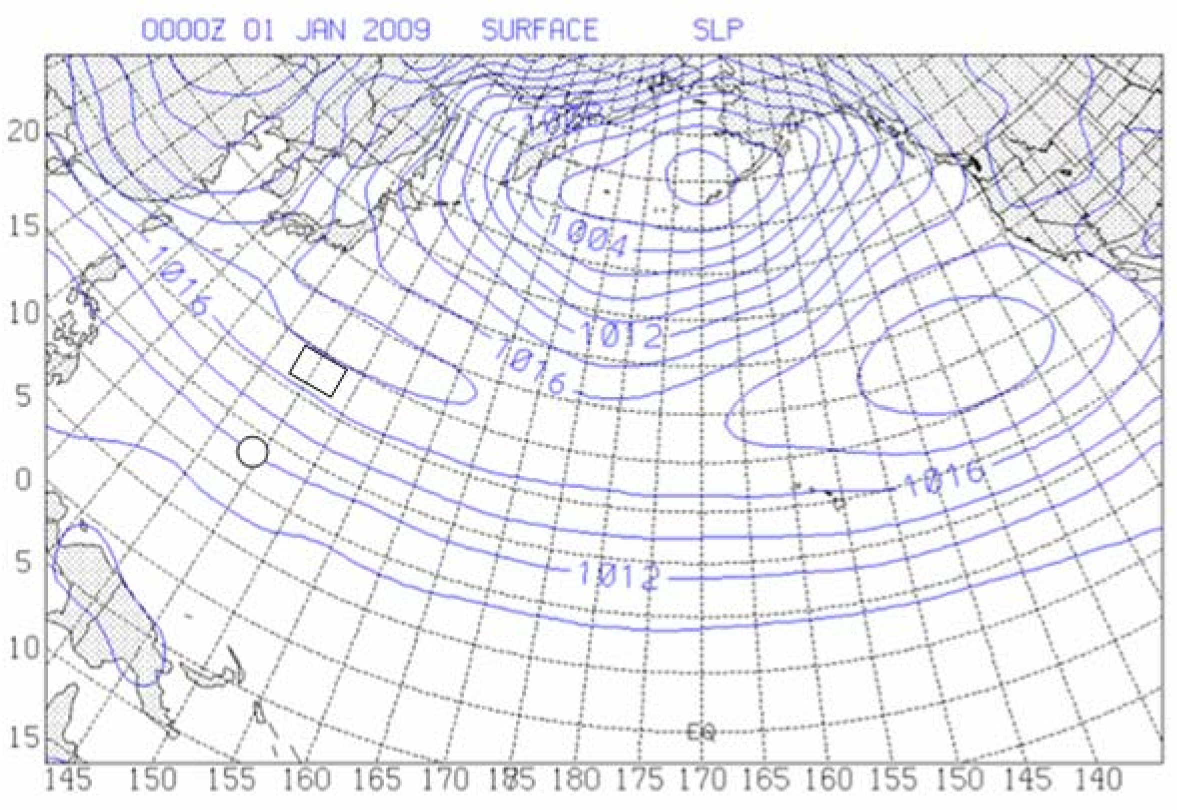

Figure 22. Average sea level pressure pattern over the Pacific at 00 UTC for 25 knots or greater cases. The dot represents the approximate location of Guam

Figure 23 is a North to South cross section over the island of Guam (approximately 144° E) at 00 UTC from roughly 30°N on the left to 5°N on the right. The structure is similar to the Hickam cross section in that there is relatively low static stability below 925 mb indicated by the steepness and widely spaced insentropes, which

are capped by increased stability above due to the presence of the trade wind inversion. Examining the other times show diurnal changes in the static stability with the lowest stability being between 00 and 06 UTC, 1000-1600 local time, and the strongest static stability occurring at 12 UTC, 2200 Local time. Analyzed winds are 8-9 m s^{-1} near Guam with little diurnal change, however winds of 10 m s^{-1} or more are seen aloft. Geostrophic flow (not shown) across Guam is 17 m s^{-1} at 06 UTC, 1600 local time, substantially greater than that at Hickam. Although observations show that wind gusts above 25 knots may happen at any hour, the majority coincide with the times of lowest static stability.

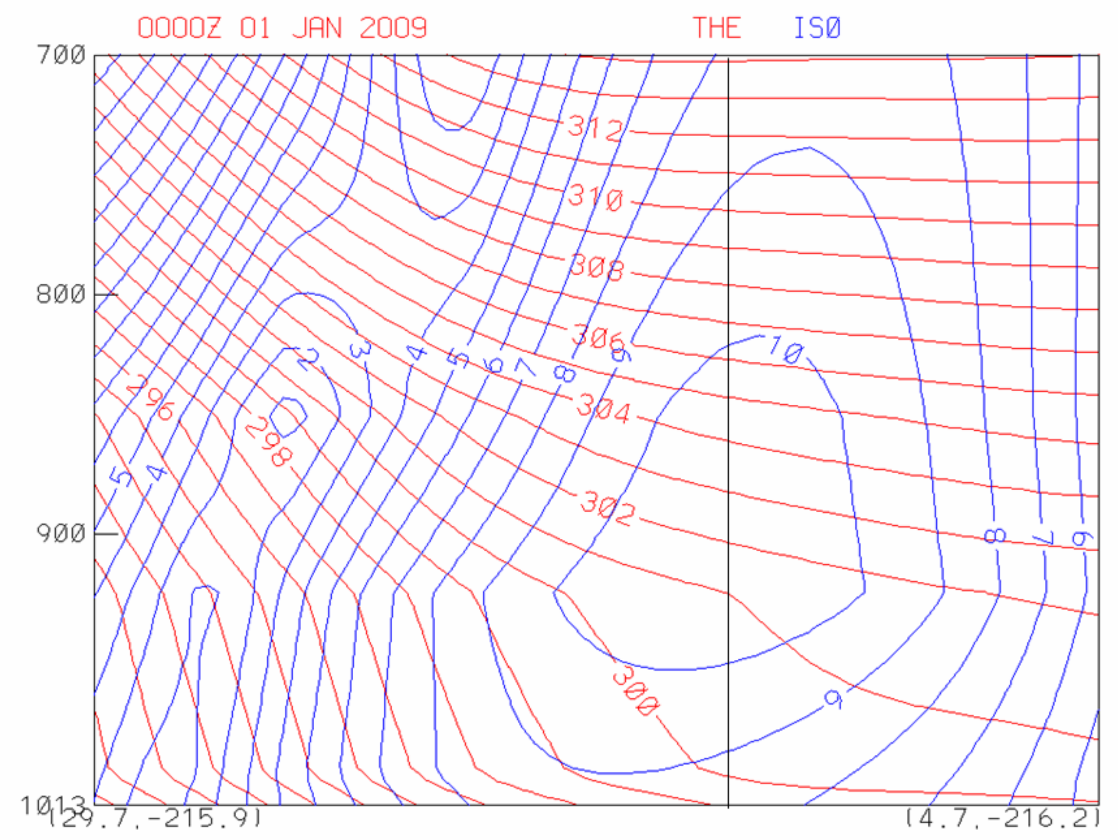

Figure 23. Cross section of the average lower troposphere at 00 UTC over the island of Guam, near Andersen AFB, for 25-knot cases. Line denotes the approximate location of Guam

2. Climatological Average Conditions for Winds 15–24 Knots

Figure 24 shows the average sea level pressure pattern over the Pacific for the 15-24 knot cases at Guam. A few differences can be seen between the two averages. First,

the Siberian High has retreated well to the west and no longer protrudes into the Pacific north of Guam. Over the diurnal cycle, the high never extends eastward (not shown). Second, the eastern Pacific sub tropical high now is much broader and extends much further to the west than with the 25-knot average. Next, the area of low pressure that was centered near the Aleutians is now much further west and also not quite as deep, with an approximate strength of less than 1004 mb. Lastly, the average location of the 1012 mb contour is now south of Guam and, in conjunction with the retreat of the Siberian High, indicates that the pressure gradient near Guam has weakened which was verified by geostrophic flow analyzed at 10 m s^{-1}, well below 25-knot climatology.

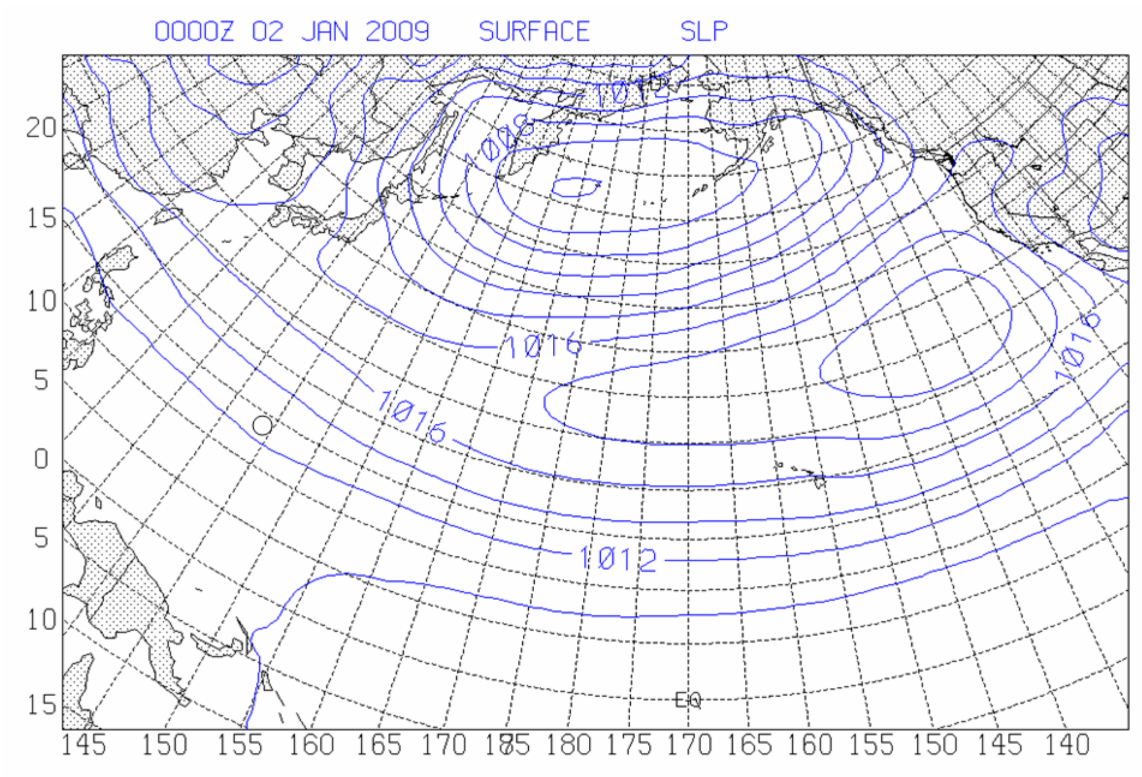

Figure 24. Average sea level pressure pattern over the Pacific at 00 UTC for the 15-24 knot cases

Figure 25 shows a cross section at 00 UTC along the same path over Guam. The differences between the structures on high versus low wind days are similar to those found with the Hickam cross sections. First, the isentropes are not nearly as vertical as they were in the 25-knot average wind days, indicating increased static stability in the

lower layers, which changes only slightly diurnally. Second, the winds near Guam are now in the 6 to 7 m s^{-1} range as the stronger winds have retreated further south. Lastly, there is still stronger winds above the surface associated with the inversion; however those winds are less also, now under 9 m s^{-1}. These differences suggest less potential for vertical mixing and lower wind gusts should it occur given the slower wind speed at the top of the trade wind inversion.

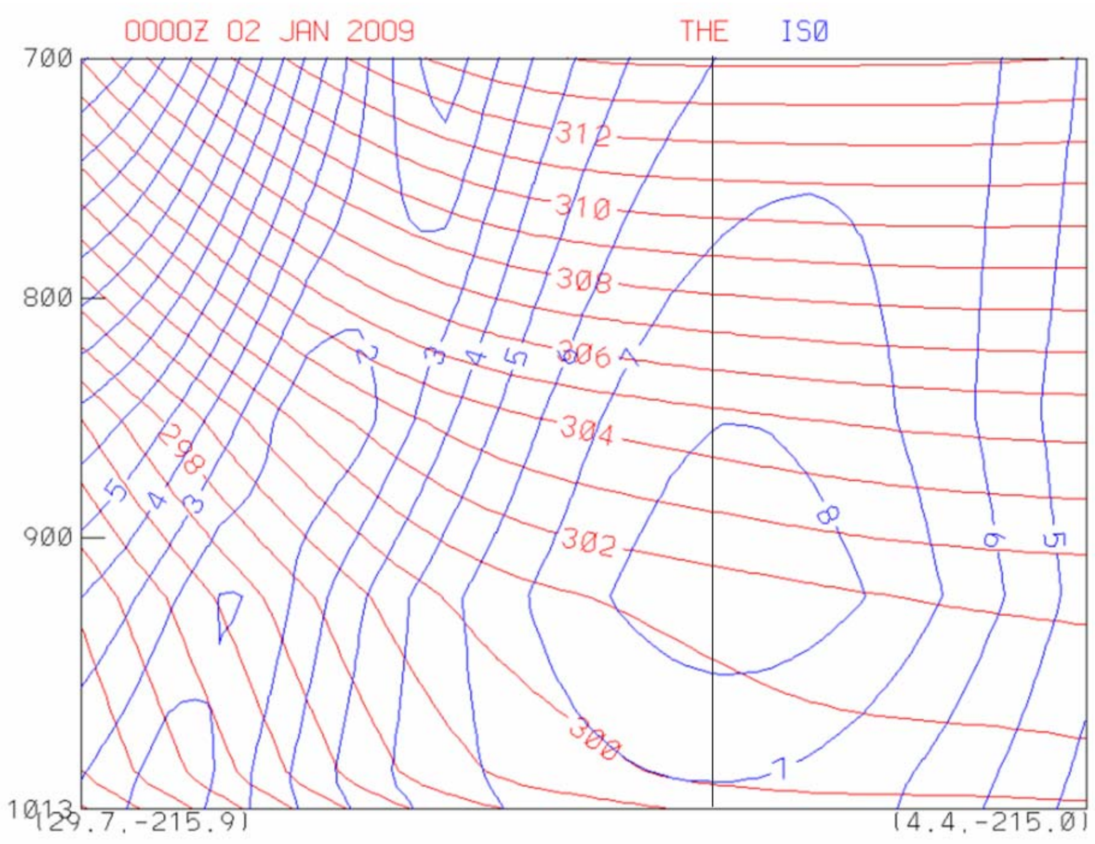

Figure 25. Cross section of the average lower troposphere at 00 UTC over the island of Guam, near Andersen AFB, for the 15-24 knot cases. Line denotes the approximate location of Guam

C. CASE STUDIES

The following cases were examined to highlight the variability in the synoptic pattern. Individual synoptic patterns do not necessarily resemble the climotological averages but may or may not produce wind gusts of a particular speed. For instance, a day where the winds gusted above 25 knots may have resembled the 15-24 knot climotological pattern when comparing the sea level pressure. Several cases in which

this occurred were identified and examined. “Hits” are days in which the pattern appears to be the 15-24 knot climatology pattern or regime but for some reason the winds gusted above 25 knots. “No Hits”, likewise are days in which the pattern appeared to be the 25-knot or greater regime but the winds never reached that threshold. Days in which an advisory for 25 knots was issued by the 17OWS but never occurred, known as false alarms, were analyzed as well.

1. Hawaii “Hits”

a. 11 July 1996

The following sea level pressure pattern (Figure 26) is for 00 UTC on 11 July 1996 and it resembles, although not perfectly, the 15-24 knot average case. The center of the high is elongated but is located near 40°N 140°W and only varied slightly from 12 to 00 UTC. The distance from Oahu to the approximate center of the high is roughly 1,640 miles, placing Hawaii considerably outside of the 300-500 mile max wind band. Its approximate strength was 1030 mb however the 1024 mb contour is essentially in the same location as 25-knot climatology. This suggests that although the high center is too far east, it is strong enough to increase the gradient over Hawaii equivalent to 25-knot climatology. The winds gusted to 27 knots and twice to 25 knots within several hours of the time of this chart.

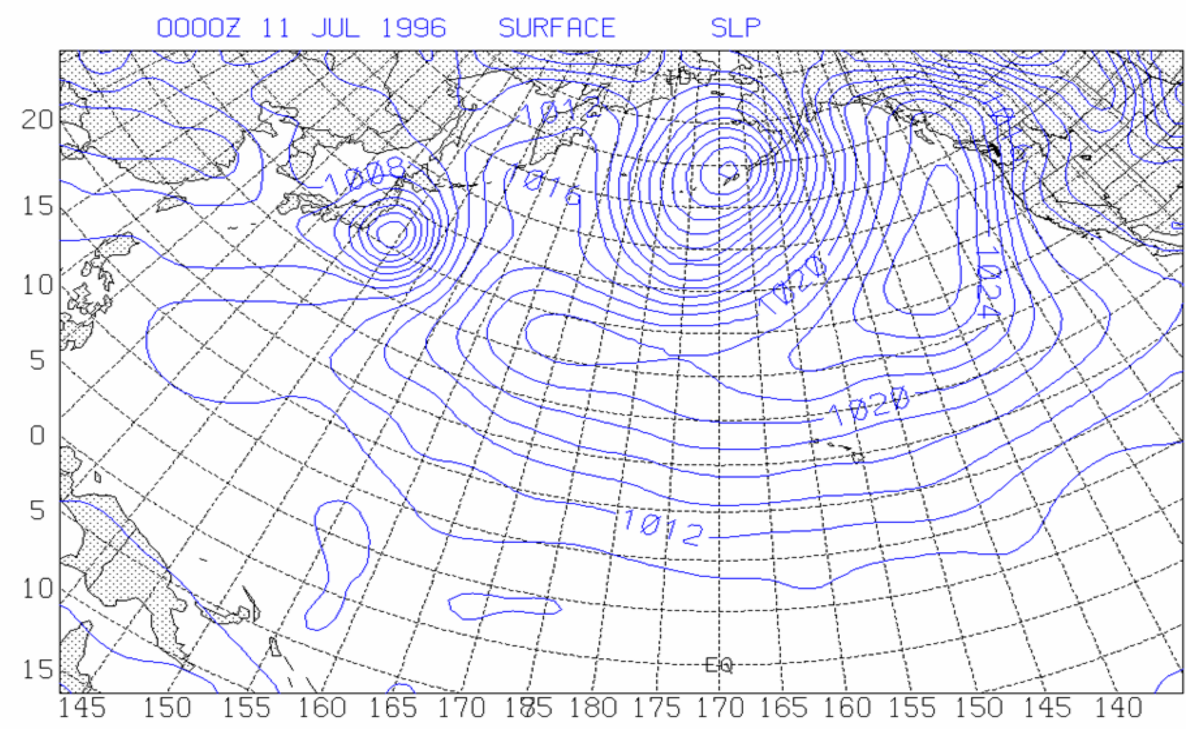

Figure 26. Sea level pressure pattern for 00 UTC 11 July 1996 that appears to match 15-24 knot climatology

Figure 27 below is the cross section roughly along the same location as the climotological averages. Upon examination of the isentropes and isotachs, one can see fairly good static stability in the lower layers over Hawaii; however 8-9 ms^{-1} flow is seen at the 925 mb level. Upon further examination, the geostrophic flow at 18 UTC was 13 $m\ s^{-1}$ and had increased to 15 $m\ s^{-1}$ by 00 UTC, resembling that of 25-knot climatology. At 18 UTC the lower layers were slightly more stable so there was a decrease in stability. The morning radiosonde revealed 17 knots at 925 mb and fairly stable conditions but by the 00 UTC sounding winds had increased to 21 knots. This cross section appears to be a mix between the two average cases with stronger winds but increased static stability. The times of the wind gusts were between noon and 4:00 pm local, as with the vast majority of cases, leading to the belief that afternoon heating promoted mixing, which is not well represented in the synoptic analysis. Undoubtedly cases like these will occur, making it difficult to closely match one case to a particular climatological pattern.

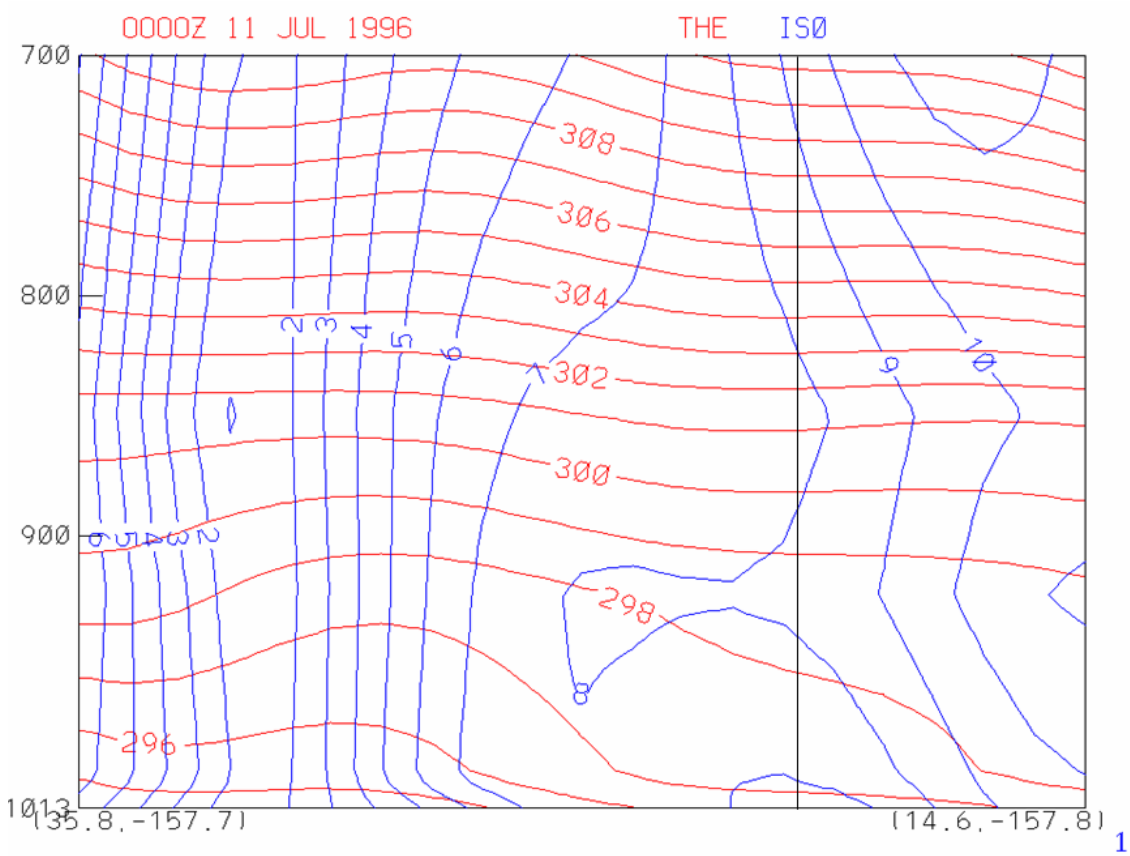

Figure 27. Cross section over Hawaii at 00 UTC 11 Jul 1996

b. 20 May 1998

Figure 28 shows the sea level pressure pattern over the Pacific for 00 UTC 20 May 1998 and is a good representation of the 15-24 knot average pattern although perhaps a little too far west. The high center is near 35°N 150°W; however the strength of the high at 1033 mb is considerably higher than that of the 15-24 knot average of 1022 mb and places the 1024 mb contour north of Hawaii as in the previous case. Hawaii is approximately 1130 miles from the center of the high. On this occasion the winds gusted from 26-27 knots for several hours around 00 UTC.

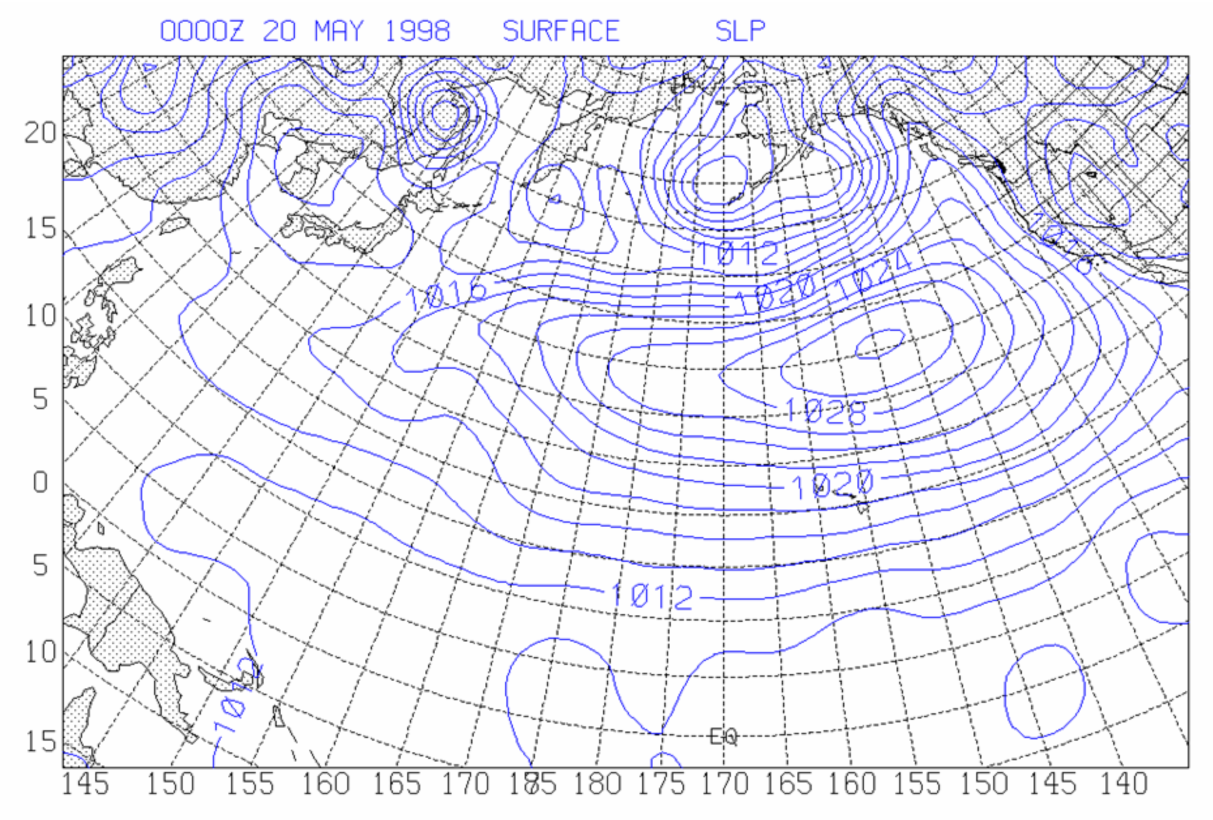

Figure 28. Sea level pressure pattern for 00 UTC 20 May 1998 resembling that of the 15-24 knot average

Figure 29 is the North to South cross section of potential temperature and winds over Hawaii at 00 UTC 20 May 1998. This structure is very similar to the structure on the cross section for 25-knot climatology (Figure 19). The boundary layer is characterized by low static stability comparable to 25-knot climatology and winds in the 8-10 m s^{-1} range. Geostrophic flow (not shown) was 15 m s^{-1} at 18 UTC and had increased to almost 19 m s^{-1} by 00 UTC, indicating the tightening gradient. Examining the other times showed very little other change in the structure diurnally. The afternoon cross section was actually a little more stable than the morning cross section in this case. The 12 UTC radiosonde also reported 20 knots at 925 mb. It is evident that when comparing the location of the 1024 mb contour, gradient, and the cross section that this pattern should be considered a 25-knot wind pattern even though the high is further east than average. The strength of the high was significant to produce a strong enough gradient to compensate the more easterly location.

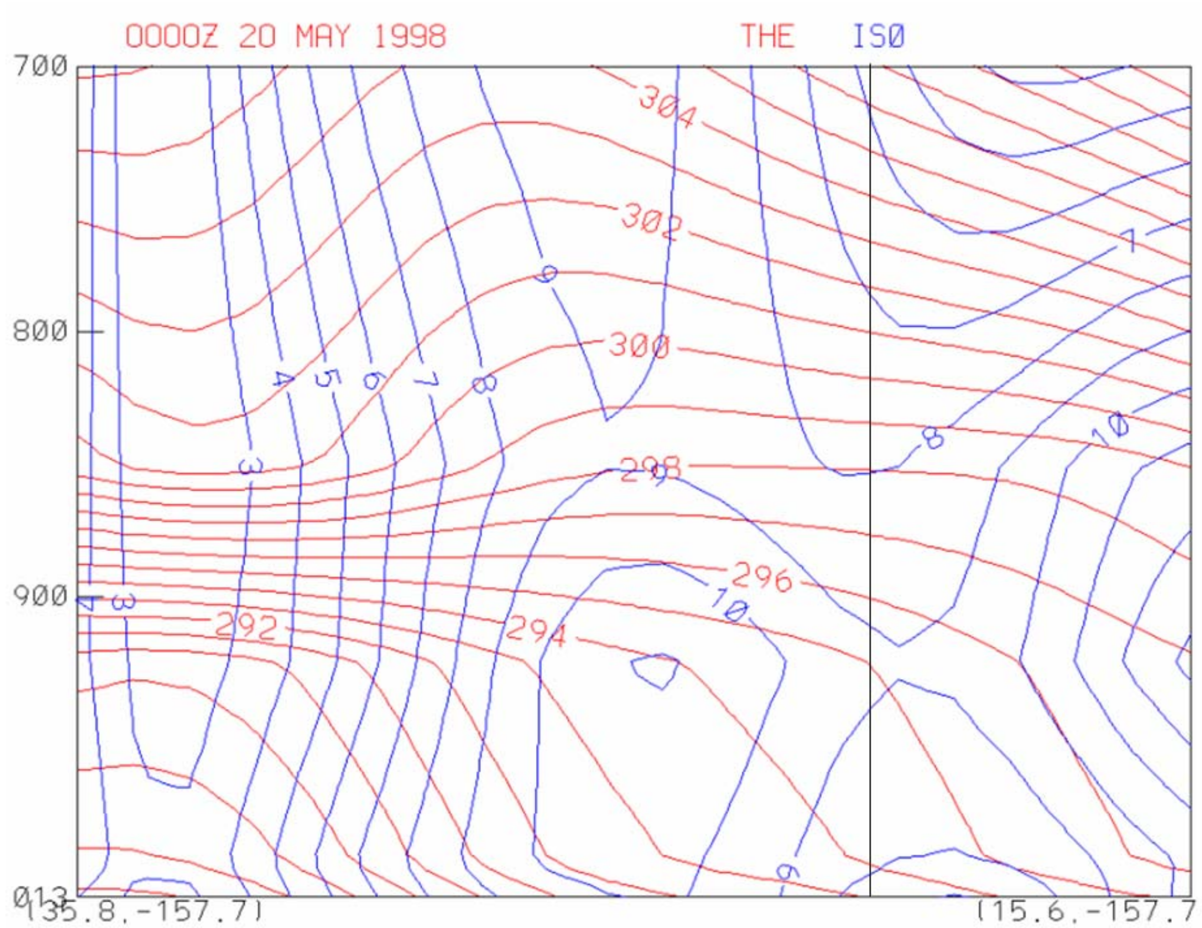

Figure 29. Cross section over Hawaii at 00 UTC 20 May 1998 resembling more like the 25 knot average

c. 10 August 2001

The conditions on 10 August 2001 appeared to match the 15-24 knot average with the center of the high well to the northeast (Figure 30). However, wind gusts above 25 knots were observed, with the winds gusting to 30 knots just before 00 UTC. The high center was near 40°N 145°W with a strength of 1028 mb and located approximately 1300 miles north northeast of Hickam. This again places the islands much further away from the 300-500 mile zone and it does not appear strong enough to increase the gradient as in the previous cases.

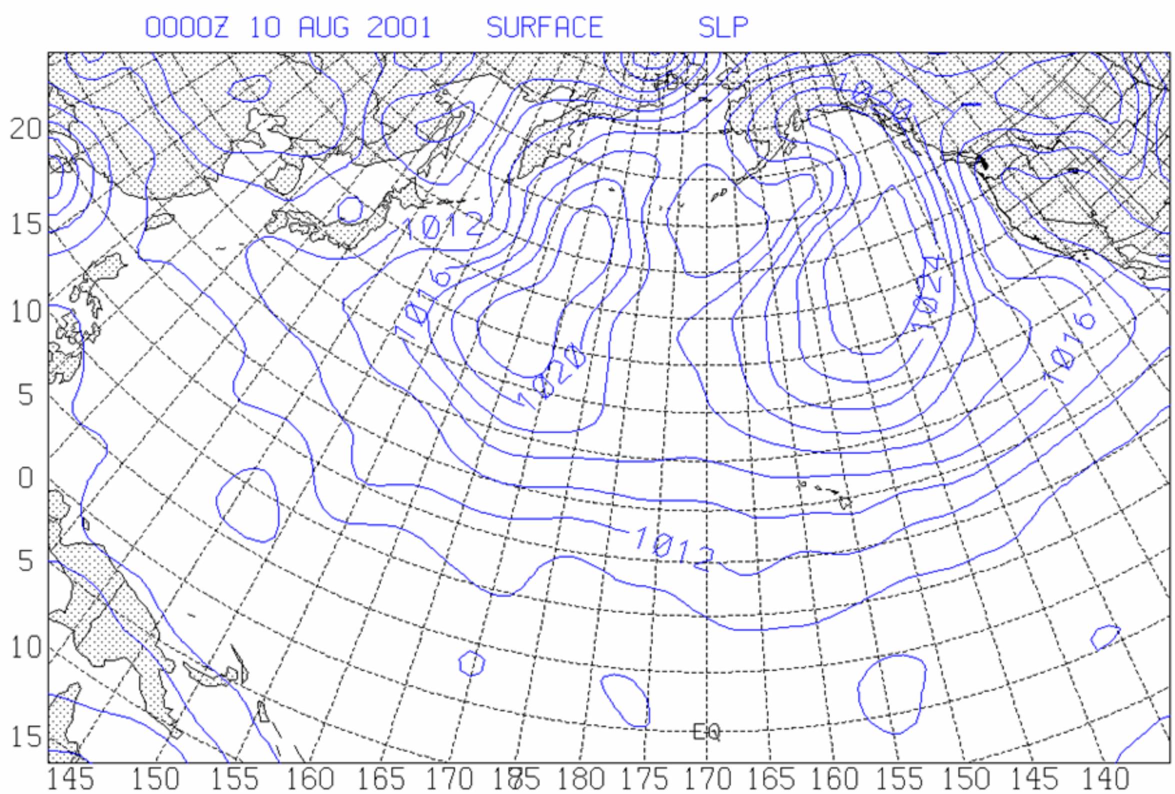

Figure 30. Sea level pressure pattern for 00 UTC 10 August 2001 that is similar to the 15-24 knot average

Figure 31 is the cross section of potential temperature and winds over Hawaii at 00 UTC. It is very clear that this cross section more closely matches the cross section climatology for 25-knot winds. When compared to that cross section, one can see the similar structure of isentropes indicating the decreased static stability in the boundary layer. Winds are also in the 8-10 m s^{-1} range, stronger than that of the 25-knot average and were even 1-2 m s^{-1} stronger at 18 UTC. Although geostrophic wind analyses indicated the flow was only just over 12 m s^{-1} from 18-00 UTC, this was still above 15-24 knot climatology. Soundings for this day were not as helpful as the morning observation indicated 10-15 knots up to 925 mb but had increased to 18 knots by the afternoon. Although this case did not fit climatology in the sea level pressure pattern it is clear the decreased static stability readily allowed the stronger winds aloft to mix to the surface, promoting a prime condition for wind gusts above 25 knots.

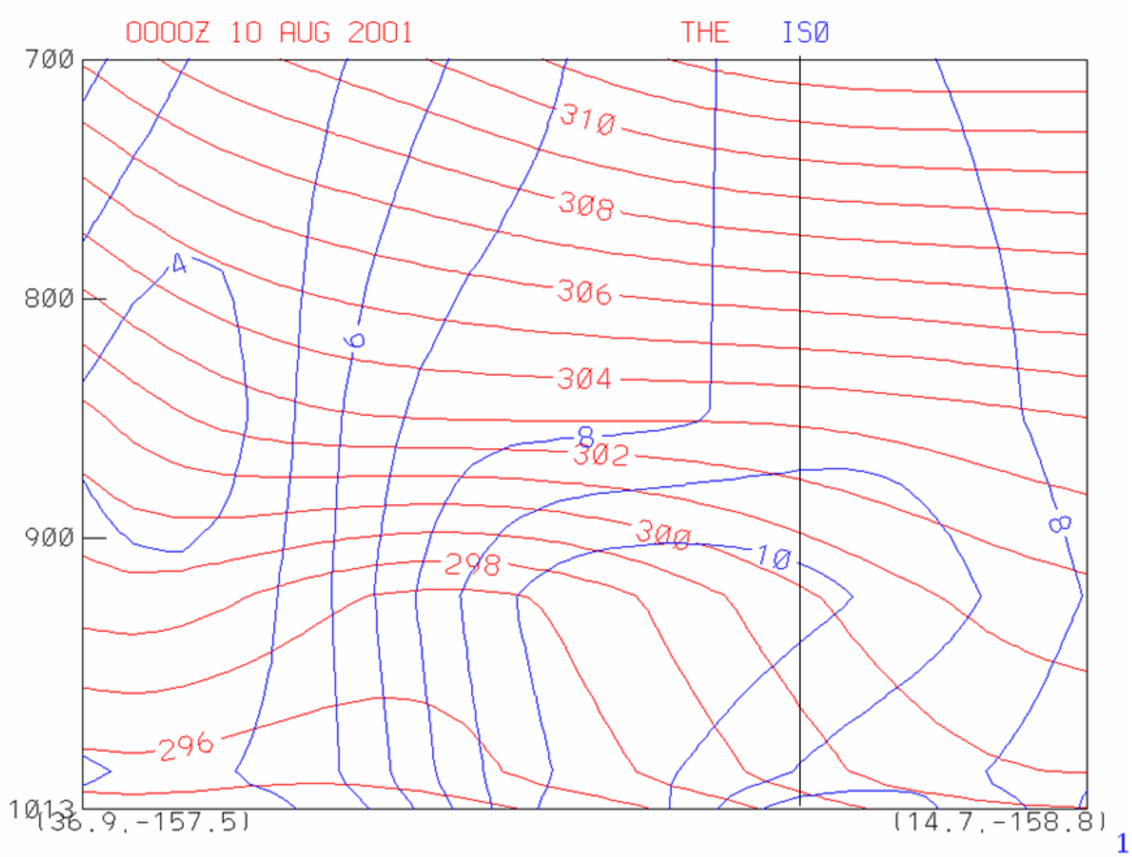

Figure 31. Cross section over Hawaii at 00 UTC 10 August 2001 resembling more like the 25-knot or greater average

2. Hawaii "No Hits"

a. 25 June 1996

Figure 32 is the sea level pressure pattern for 00 UTC 25 June 1996. This pattern has aspects of both climatologies, but more closely resembles the 25-knot or greater climatology synoptic with the high positioned pretty far west. The high center is near 37°N 153°W which is approximately 1,175 miles away from Hickam AFB. Its strength was 1032 mb, which was well above the climatological average. While this synoptic pattern appears to be highly favorable to produce 25 knot winds, none were observed. Although very close, the winds gusted from 18-24 knots for several hours but never crossed the threshold of 25 knots.

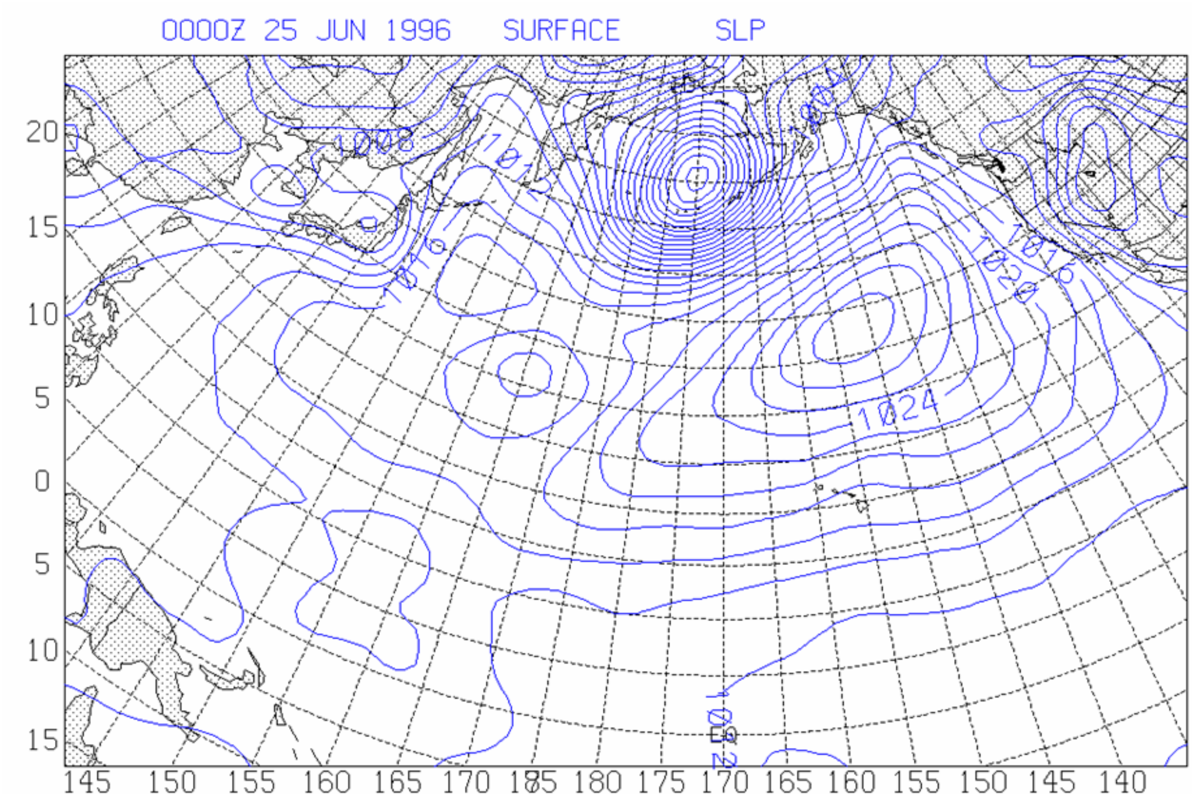

Figure 32. Sea level pressure pattern over the Pacific for 00 UTC 25 June 1996 resembling that of the 25 knot or greater average

The cross section for this case (Figure 33) however does resemble 15-24 knot climatology although it is difficult to judge. Static stability comparable to the average exists in the 925 to 1000 mb layer as well as winds of 7-8 m s^{-1} and only slight changes diurnally were found. Geostrophic flow more closely matched 25-knot climatology, 16 m s^{-1} from 18-00 UTC, but not realized near Hickam as analysis shows. The morning sounding reported 21 knots at 925 mb and slightly less stability by the afternoon but lower wind speeds of 15-17 knots as well. Upon examination of the 18 UTC cross section, stability decreased from 18 to 00 UTC but the lack of stronger winds on the large scale seems to have prevented winds from crossing the 25-knot threshold.

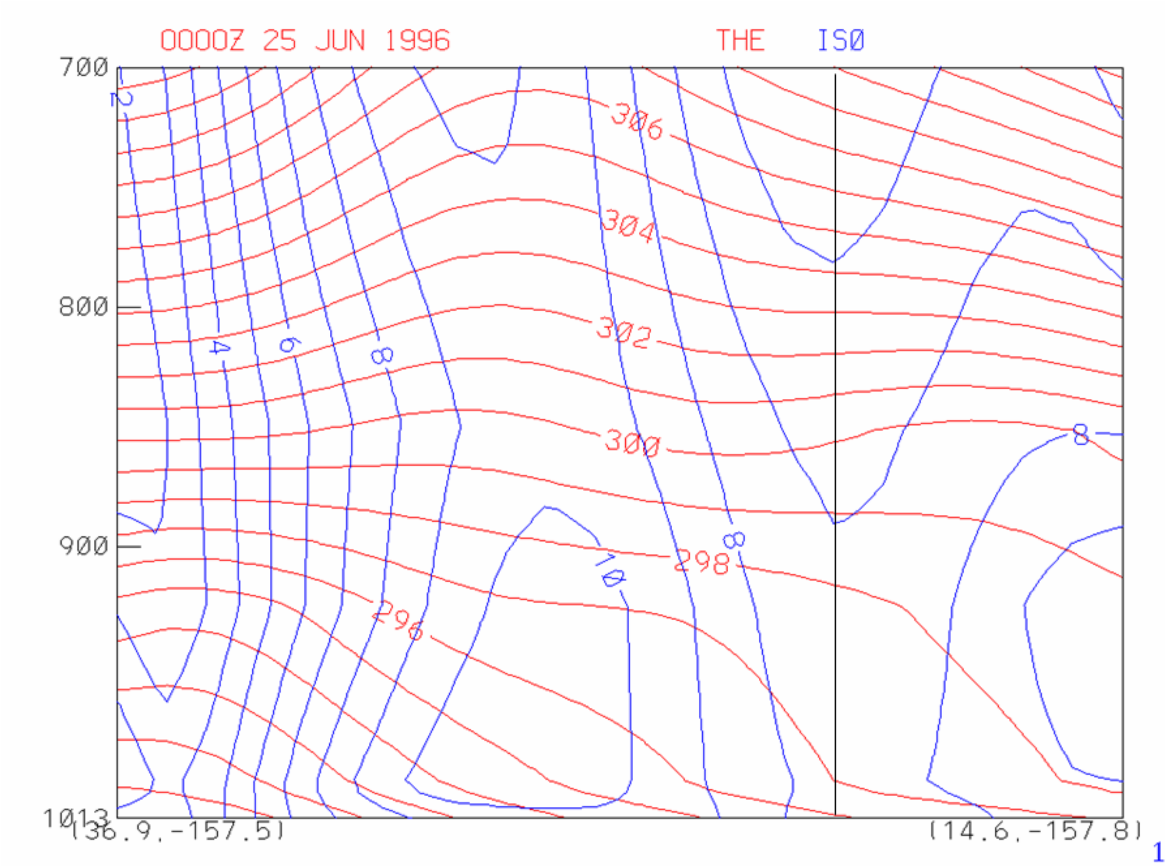

Figure 33. Cross section over Hawaii on 00 UTC 25 Jun 1996

b. 06 July 2003

Figure 34 is the sea level pressure chart over the Pacific for 00 UTC 06 July 2003 and resembles the climatology of the 25-knot or greater cases. The high center is located at approximately 43°N and 153°W, 1500 miles from Hickam and is considerably north of 25 knot climatology. However, its location just east of Hawaii and its intensity of 1033 mb tend to offset its northerly location making for a good 25-knot candidate. A gust to 20 knots was all that was reported on this day.

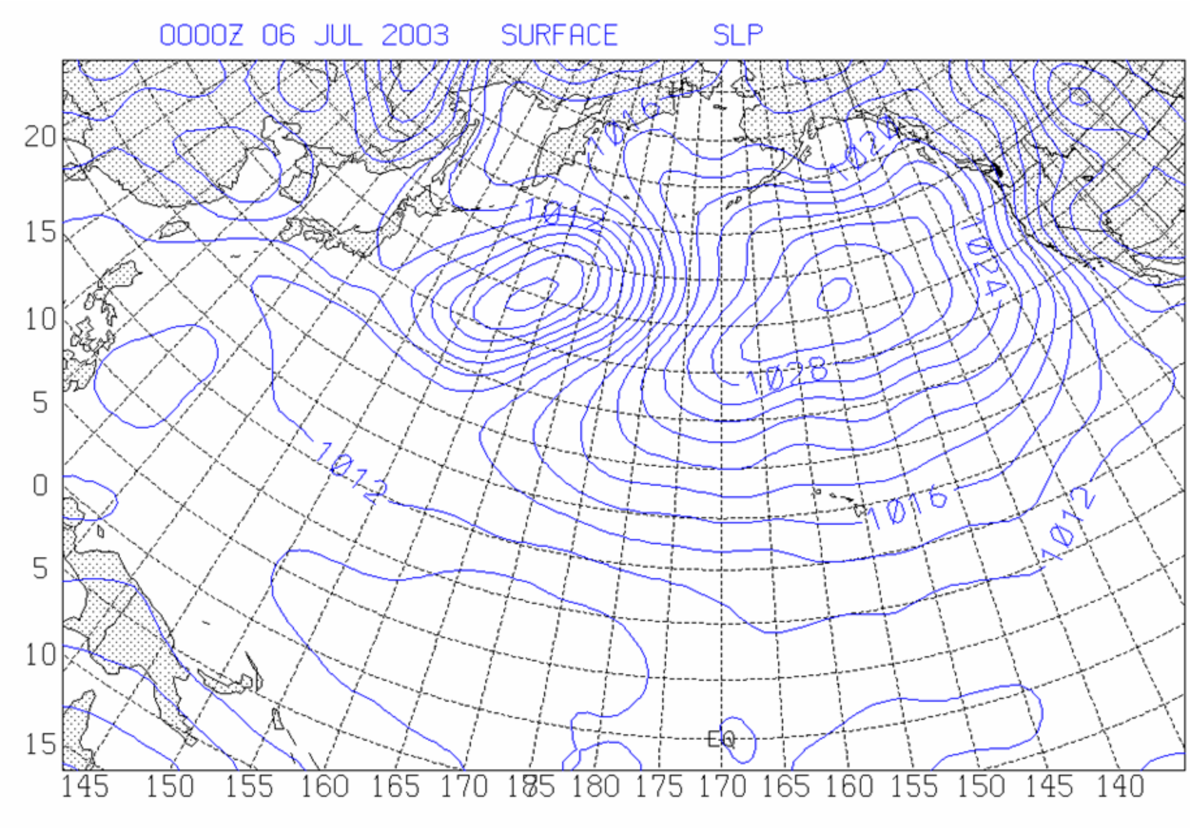

Figure 34. Sea level pressure chart over the Pacific for 00 UTC 06 July 2003 resembling the 25 knot average

It is clear from examination of this case's cross section (Figure 35) that the boundary layer more closely matches that of 15-24 knot climatology. Stability did not vary diurnally and winds remained light as soundings for the day indicated only 14 knots at 925 mb. The geostrophic flow over Hawaii also compared to 15-24 knot climatology as it was only 10 m s^{-1}. Higher static stability combined with the lack of strong geostrophic flow seems to be the reason the winds never gusted above 20 knots.

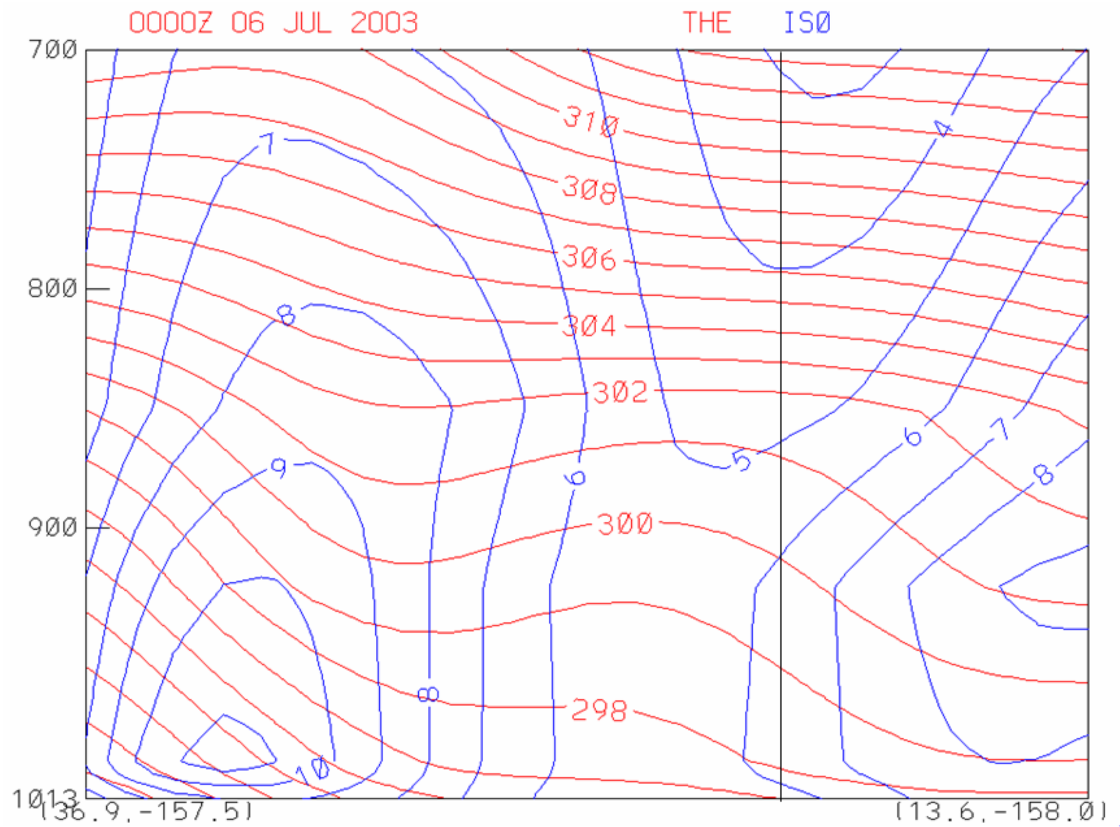

Figure 35. Cross section over Hawaii for 00 UTC 06 July 2003 resembling the 15-24 knot average

c. *16 August 2006 False Alarm*

The following case is one of 19 false alarm events provided by the 17OWS. Of the 19 false alarms, 12 resembled the 15-24 knot climatology, six looked like a mixture of the two or possibly the 25-knot climatology, and one appeared to be a kona storm. Figure 36 is the sea level pressure pattern for 00 UTC 17 August 2006 which is 1400 local time on 16 August. With a high center near 44°N 142°W and a pressure of greater than 1030 mb, the case does resemble 15-24 knot climatology, although the pressure is higher than the average. Most notably the strength of the pressure gradient over Hawaii is of similar intensity to the 15-24 knot climatology even though the structure of the high is not. The highest gust reported was 21 knots.

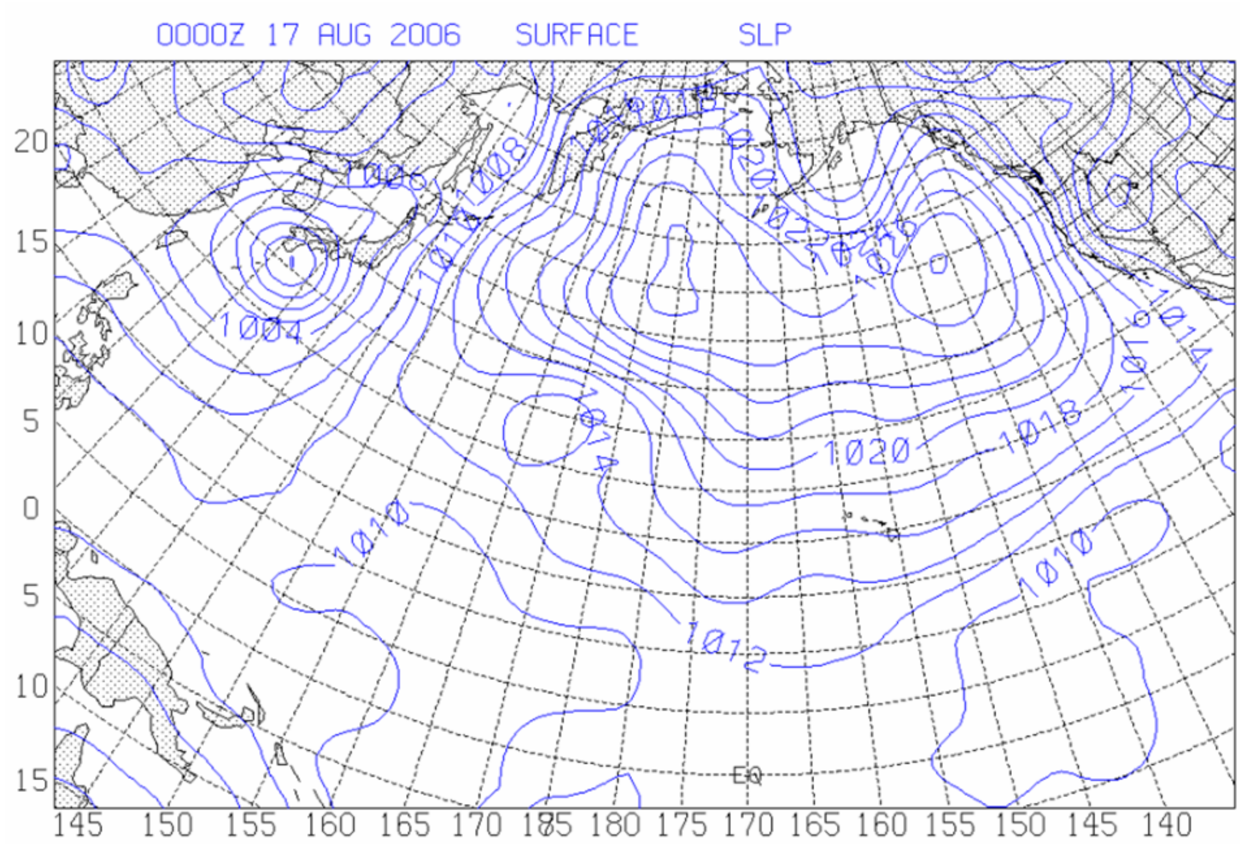

Figure 36. Sea level pressure pattern over the Pacific for 00 UTC 17 August 2006 resembling 15-24 knot climatology

Upon examination of the cross section (Figure 37), the static stability in the boundary layer appears to be between the two averages; however the surface flow is only 6-7 m s^{-1}, even less aloft, and the geostrophic flow over Hawaii was 11 m s^{-1}, as the weaker gradient suggests. The morning sounding reported 15 knots at 925 mb and had decreased to 10 knots by the afternoon sounding. The 18 UTC cross section also resembled 15-24 knot climatology and this, compared with the sea level pattern, were good indicators that the winds would remain below 25 knots.

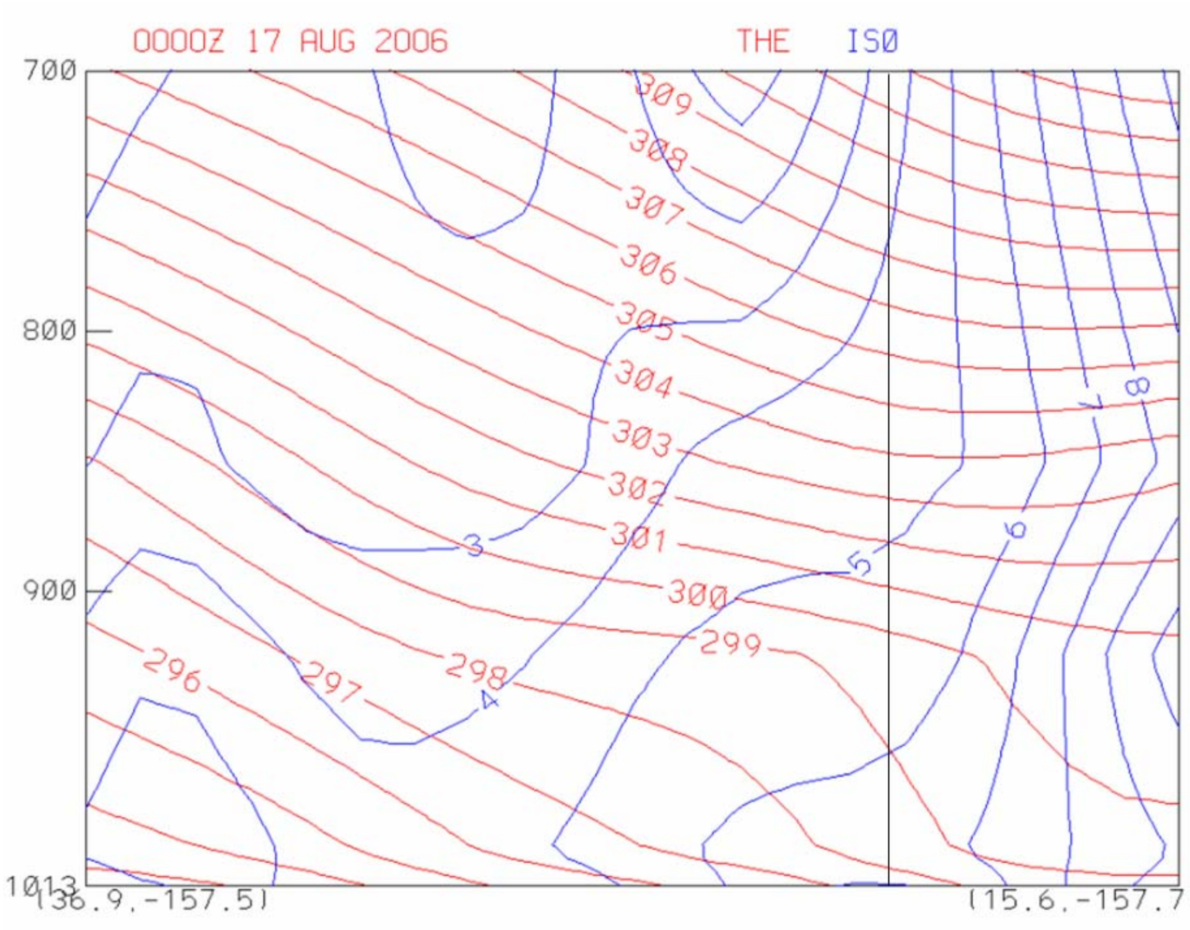

Figure 37. Cross section over Hawaii for 00 UTC 17 August 2006

3. Guam "Hits"

a. 06 May 1998

Figure 38 is the sea level pressure pattern near Guam for 00 UTC 06 May 1998 which was a day that produced wind gusts above the threshold. The extension of the high from the east and not from Asia is comparable to 15-24 knot climatology for Guam. Although there is a 1025 mb high center approximately 1460 miles north of Guam, the air base is well outside of the 300-500 mile max wind zone. However, the pressure gradient over Guam is stronger than the 25-knot climatology which may explain the 26 knot wind gusts reported on this day. The geostrophic flow over Guam at 00 UTC was an astonishing 23 m s^{-1}, dramatically higher than 25-knot climatology.

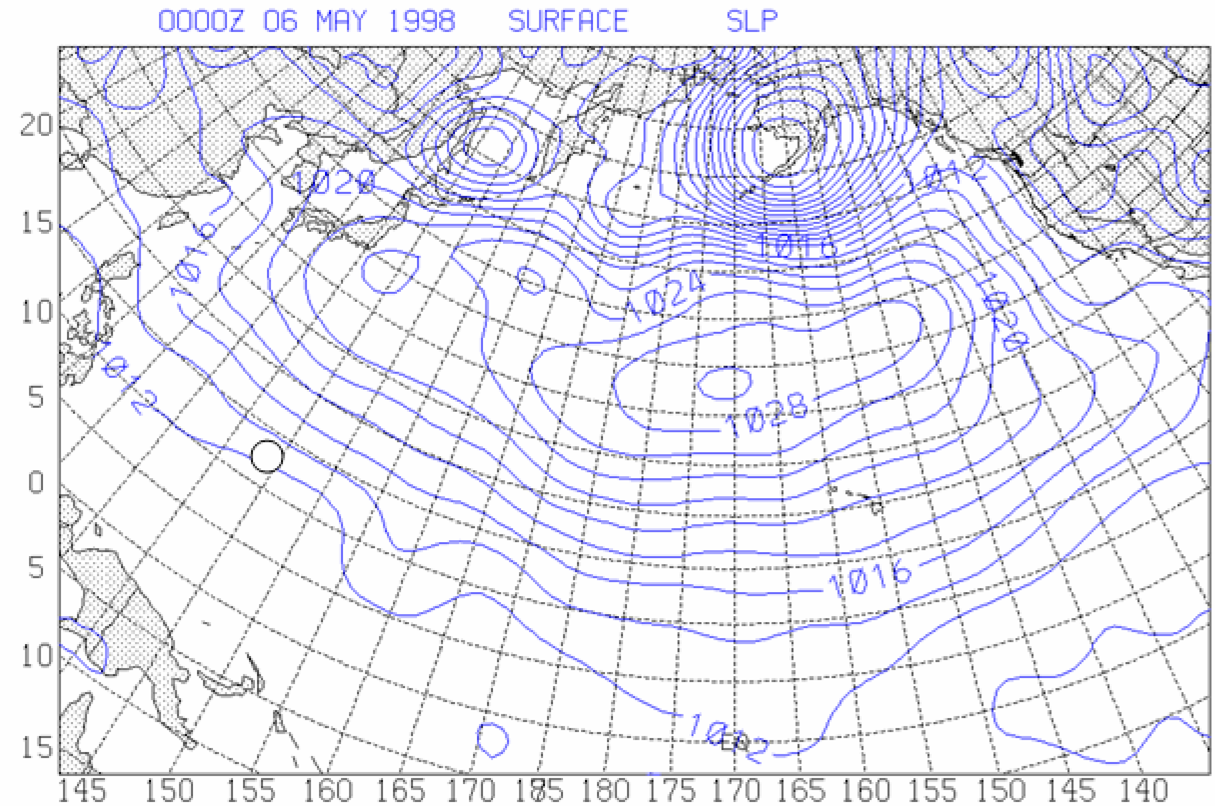

Figure 38. Sea level pressure pattern near Guam for 00 UTC 06 May 1998 and resembles the 15-24 knot average

Figure 39 is the cross section of potential temperature and winds over the same location as the averages. Upon examination of this cross section, it is easy to see it compares fairly well with 25-knot climatology. There is even less static stability in the boundary layer than in the 25-knot average and winds are also greater at 10-13 m s^{-1} which is consistent with the strong sea level pressure gradient in figure 38. Although, at first look, the sea level pressure pattern resembles that of 15-24 knot climatology, once the structure of the lower troposphere is examined more closely, one can expect gusts of 25 knots or greater. Soundings for this case were not available.

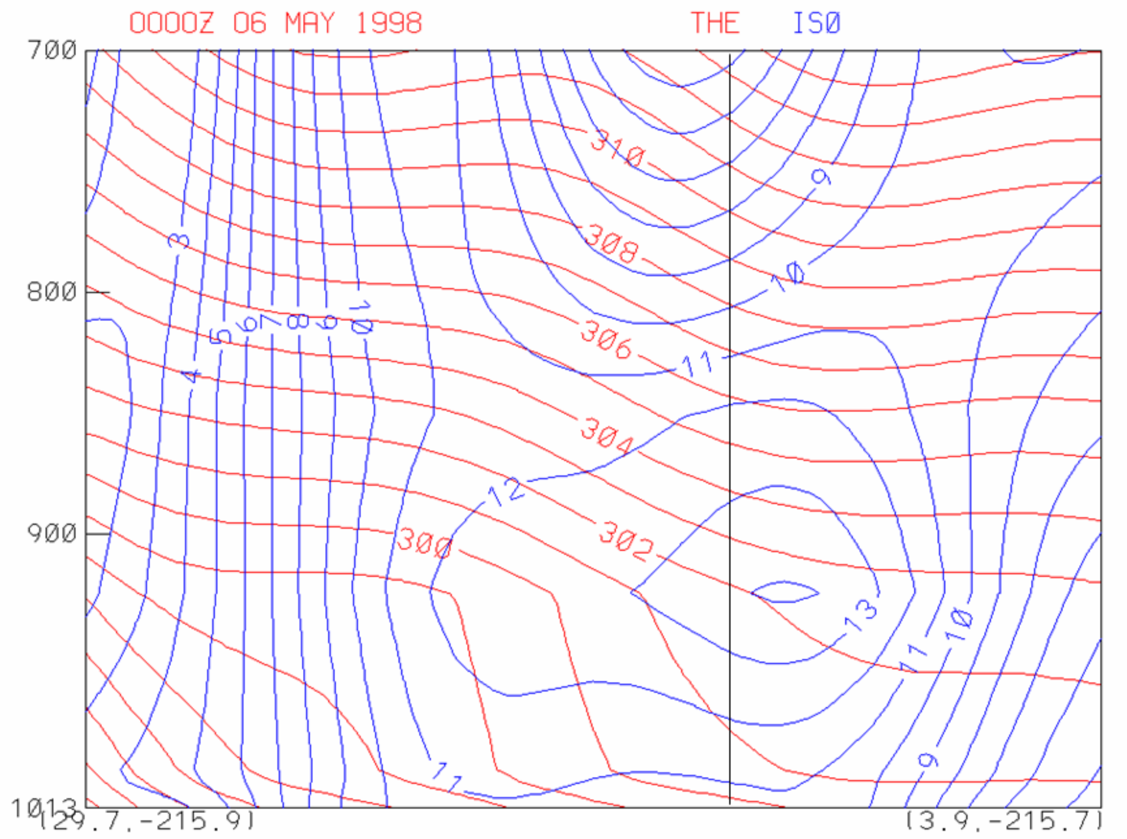

Figure 39. Cross section over Guam for 00 UTC 06 May 1998 resembling that of the 25 knot average

b. 22 March 1996

Figure 40 is the sea level pressure pattern for 22 March 1996 and resembles that of 15-24 knot climatology for Guam with a rather weak sea level pressure gradient over Guam as well. The subtropical high is well off to the northeast however an extension exists southwestward over Guam with the 1018 mb contour seen due north. The winds gusted to 28 knots on this day.

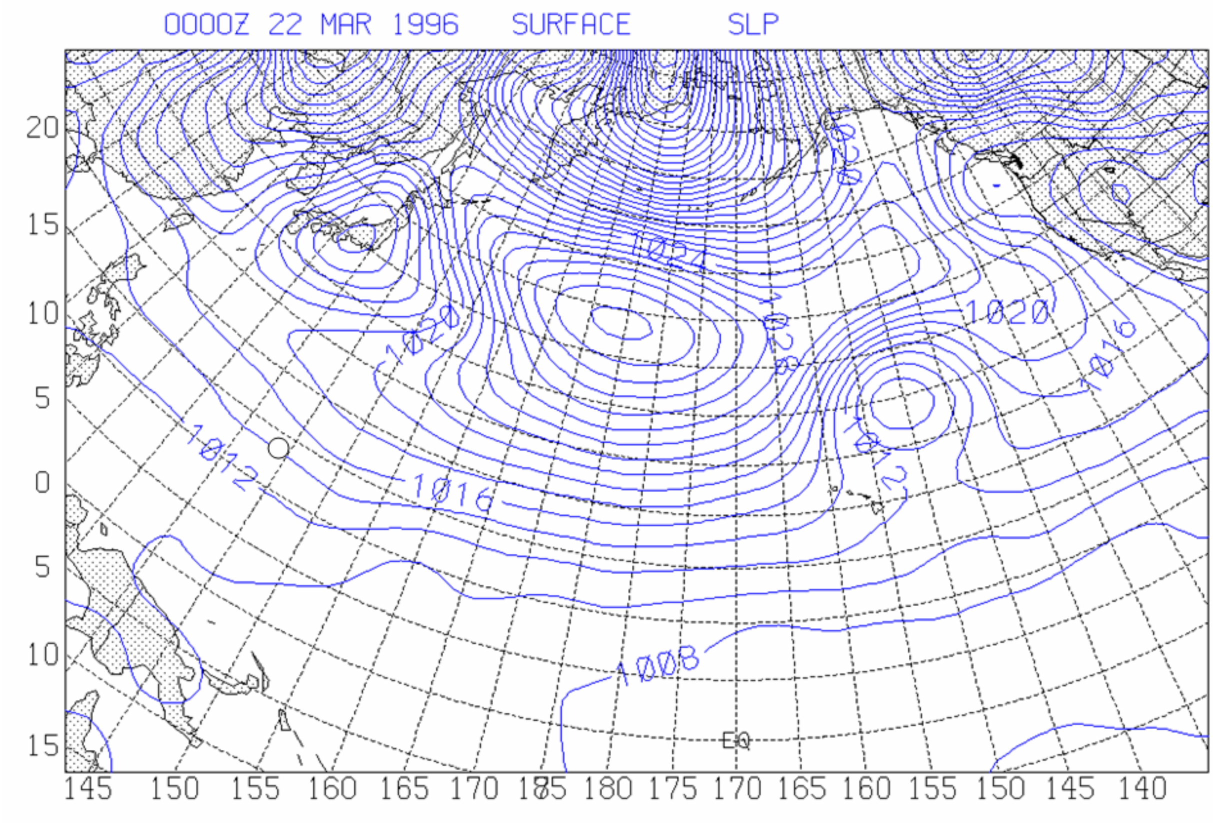

Figure 40. Sea level pressure pattern for 22 March 1996 resembling 15-24 knot climatology

Figure 41 is the potential temperature and wind cross section over Guam for this case. After examination one can see the lower layers resemble that of 25-knot climatology due to reduced static stability and stronger winds present throughout the lower troposphere over Guam. The pressure gradient over Guam is weaker than the previous case but still provides for a geostrophic flow of 19 m s^{-1}. Although the sea level pressure pattern may resemble 15-24 knot climatology, the strength of the high, lower static stability, and stronger flow suggest the occurrence of 25-knot or greater winds.

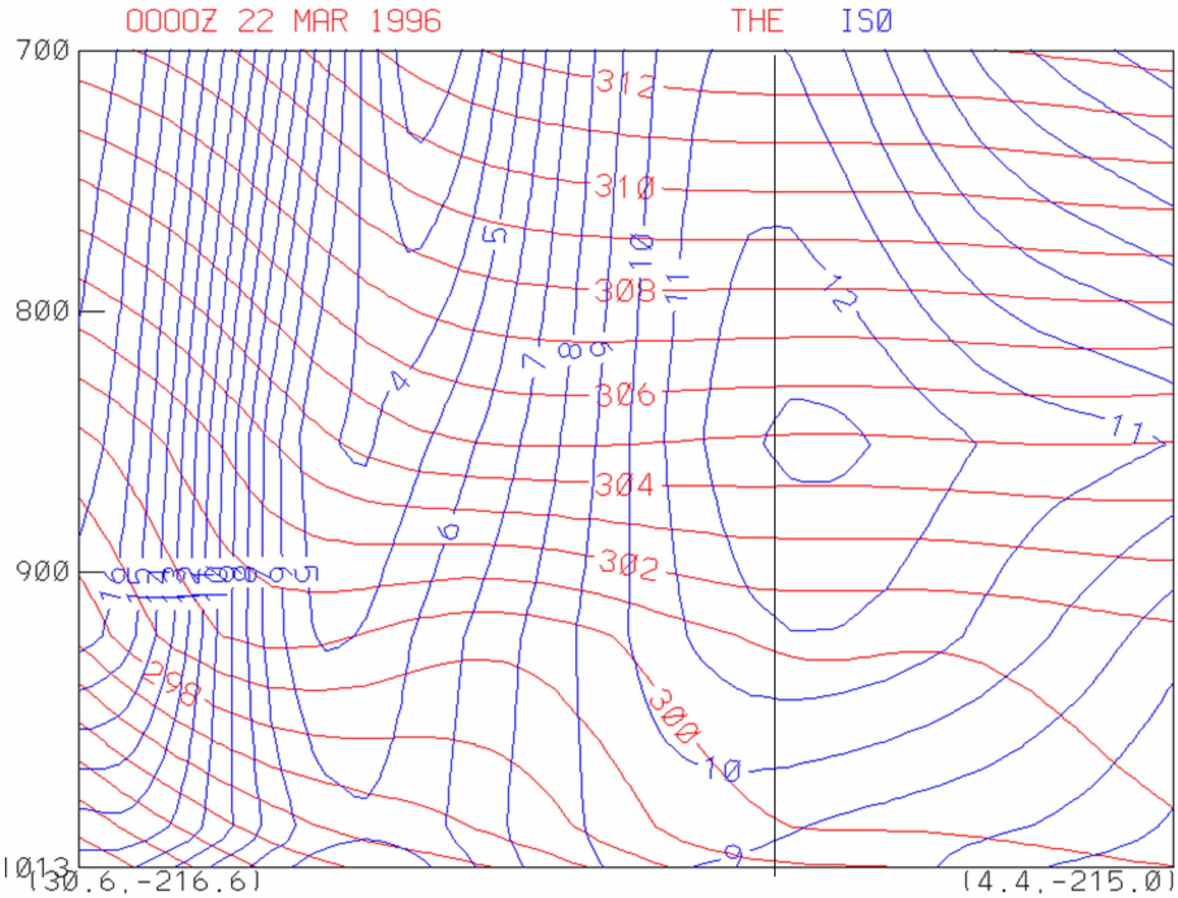

Figure 41. Cross section over Guam for 22 March 1996

c. 12 December 2003

Figure 42 is the sea level pressure pattern near Guam for 00 UTC 12 December 2003 and resembles 15-24 knot climatology since the Siberian High does not project east of Guam as in the 25-knot average. The strength of the high to the northeast was 1026 mb and was 1,785 miles from Guam. The pressure gradient over Guam seems rather week, similar to the previous case; however this case produced a wind gust exactly to 25 knots.

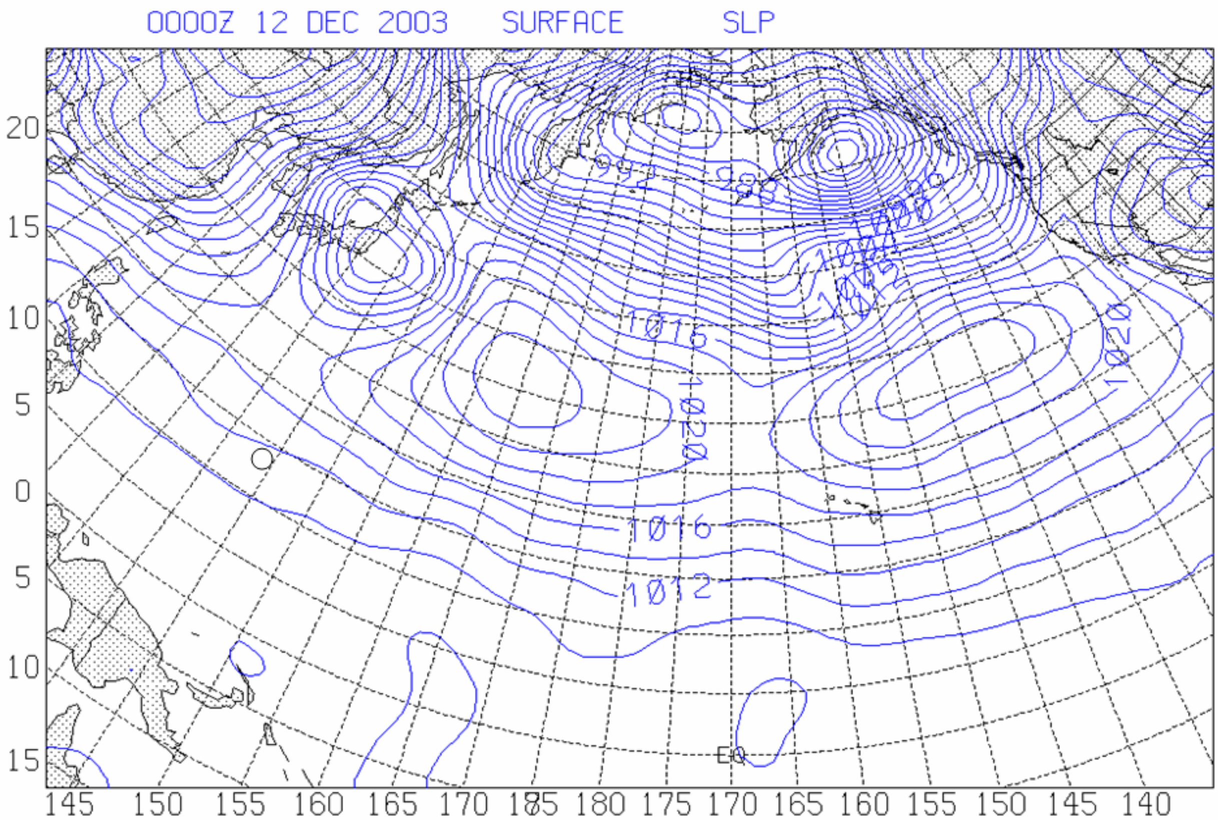

Figure 42. Sea level pressure pattern near Guam for 00 UTC 12 December 2003 resembling the 15-24 knot average

The cross section for 00 UTC 12 December 2003 (Figure 43) is fairly similar to 25-knot climatology. Low static stability is evident in the low levels, similar to the 25-knot average, which varied only slightly diurnally. Winds are 9-12 m s^{-1} in the vicinity of Guam, also consistent with the climatology. Although the pressure gradient appears to be weaker over Guam it still produced geostrophic flow of 14 m s^{-1} and soundings for this day reported 27 knots at 925 mb. The case appears to be a 15-24 knot case but after analyzing the vertical structure in the cross section and sounding, it is clear one could expect gusts of 25 knots.

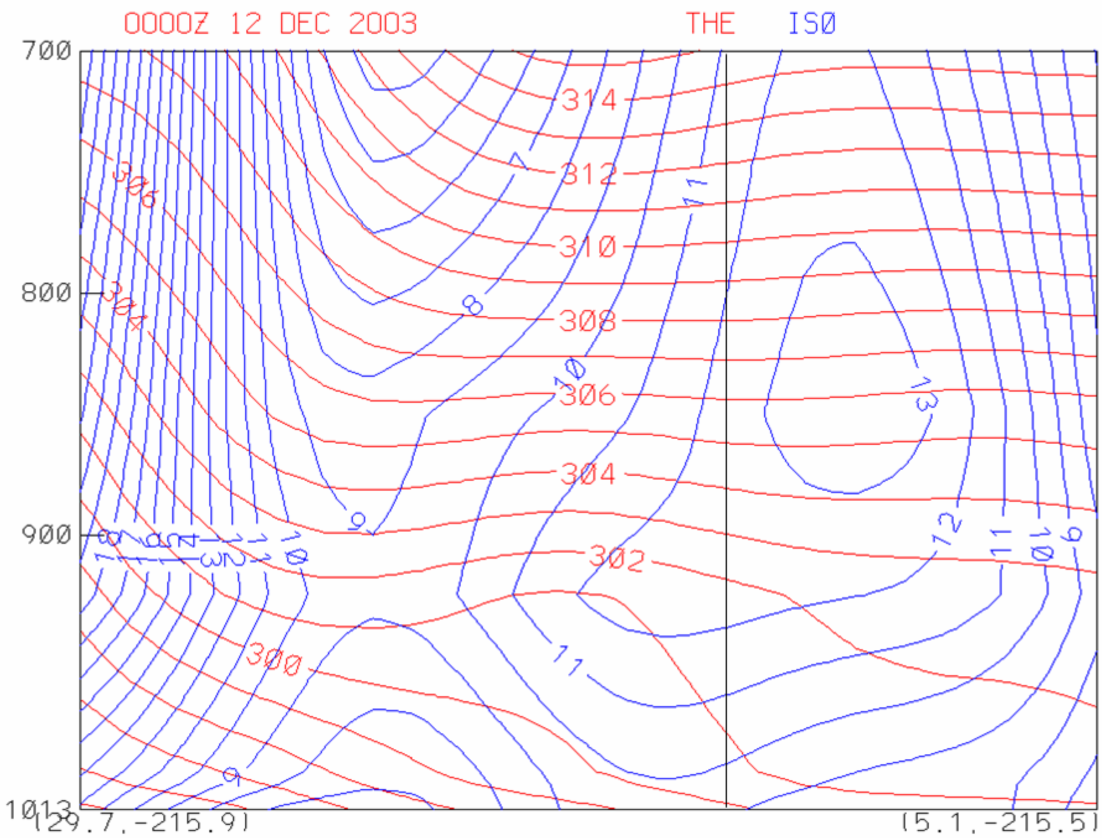

Figure 43. Cross section over Guam for 00 UTC 12 December 2003 resembling the 25 knot average

4. Guam "No Hits"

a. 26 January 1996

The sea level pressure pattern near Guam for 00 UTC 26 January 1996 (Figure 44) is a good representation of the 25-knot climatology. The Siberian High clearly noses its way out over the Pacific and to the east of Guam as in the 25-knot average. The strength of the high center; however, is near 1017 mb and was a small area located 930 miles northeast of Guam. The 25-knot climatology shows a slightly stronger high, at over 1018 mb, and closer to Guam. On this day the winds gusted between 16-20 knots for several hours but never made the 25-knot threshold, which is suggested by the sea level pressure distribution and gradient over Guam.

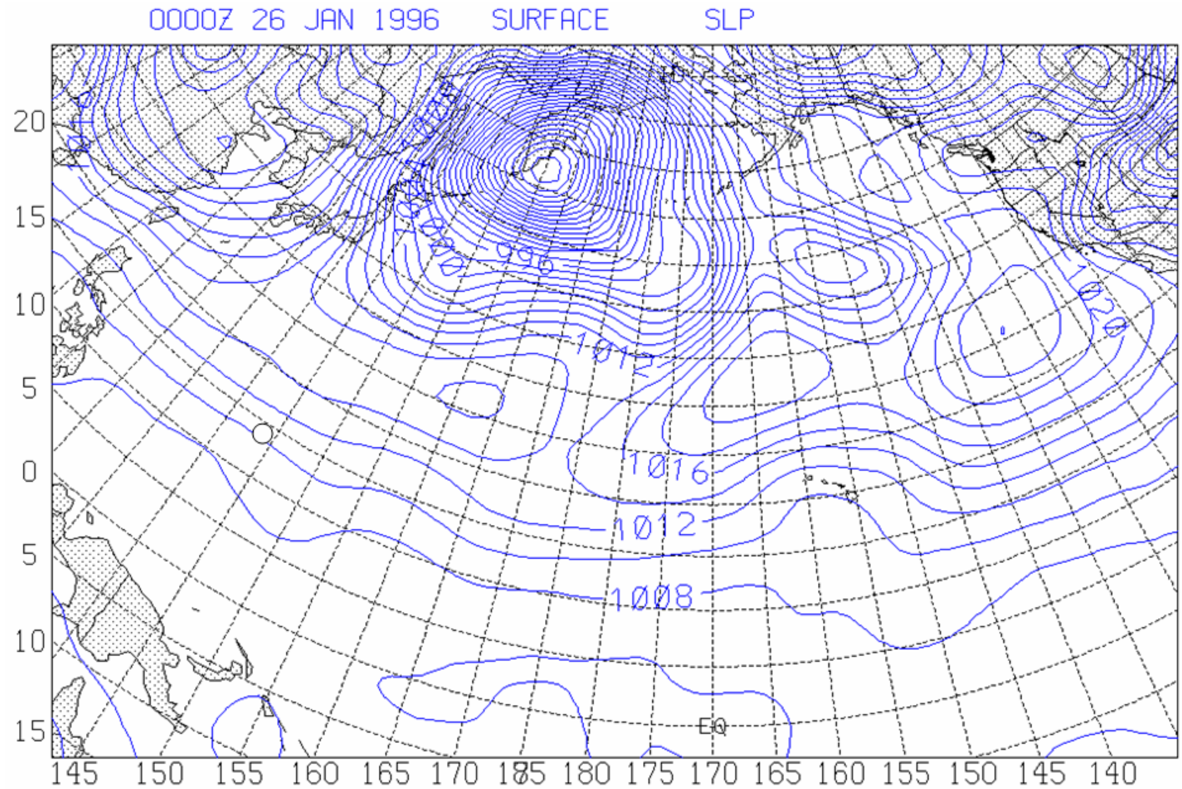

Figure 44. Sea level pressure pattern near Guam for 00 UTC 26 January 1996 resembling 25-knot climatology

The potential temperature and wind cross section for 00 UTC 26 January 1996 (Figure 45) also resembles the 25-knot climatology. As in the 25-knot average, low static stability exists in the boundary layer and winds are in the 9-11 m s^{-1} range, providing further confirmation that this day should produce wind gusts of 25 knots or greater. Furthermore, the geostrophic flow over Guam was 16 m s^{-1}, indicating the pressure gradient was stronger than it appeared. Soundings for this day were not available making it difficult to draw conclusions as to why the winds did not gust above 20 knots. The reason for weaker gusts in this case is not clearly evident in either the synoptic scale horizontal structure or vertical structure. Perhaps multiple factors were just below the thresholds to produce 25 knot winds. Clearly, subtle, local factors must have been present to prevent the stronger gusts.

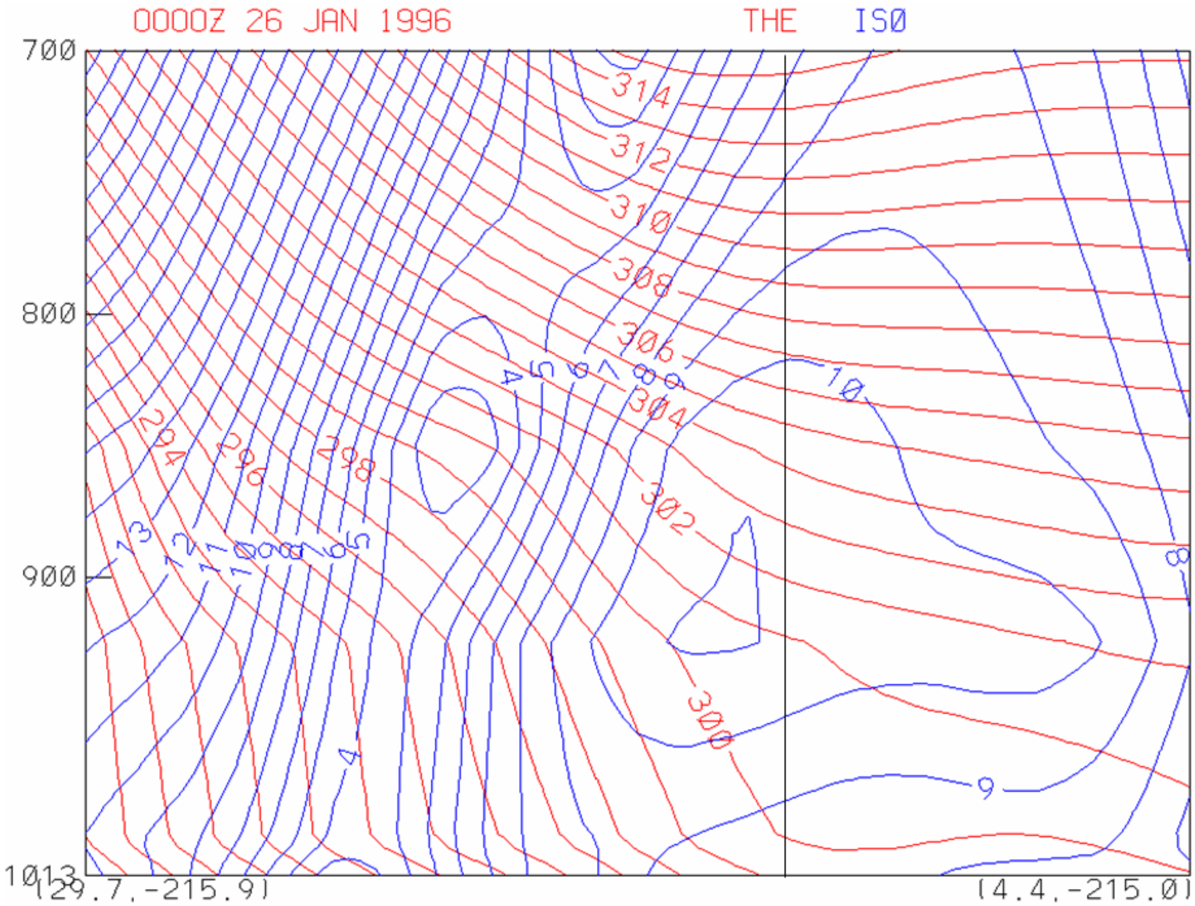

Figure 45. Cross section over Guam for 00 UTC 26 January 1996 resembling the 25-knot average

b. 19 January 1997

Figure 46 below is the sea level pressure pattern for 19 January 1997. This case resembles the 25-knot climatology due to the extension of the Siberian High east over Guam. The 1018 mb contour is roughly 600 miles north of Guam which is close to the 300-500 mile max wind zone. The winds gusted to 23 knots on this occasion, very close to the threshold but not quite enough.

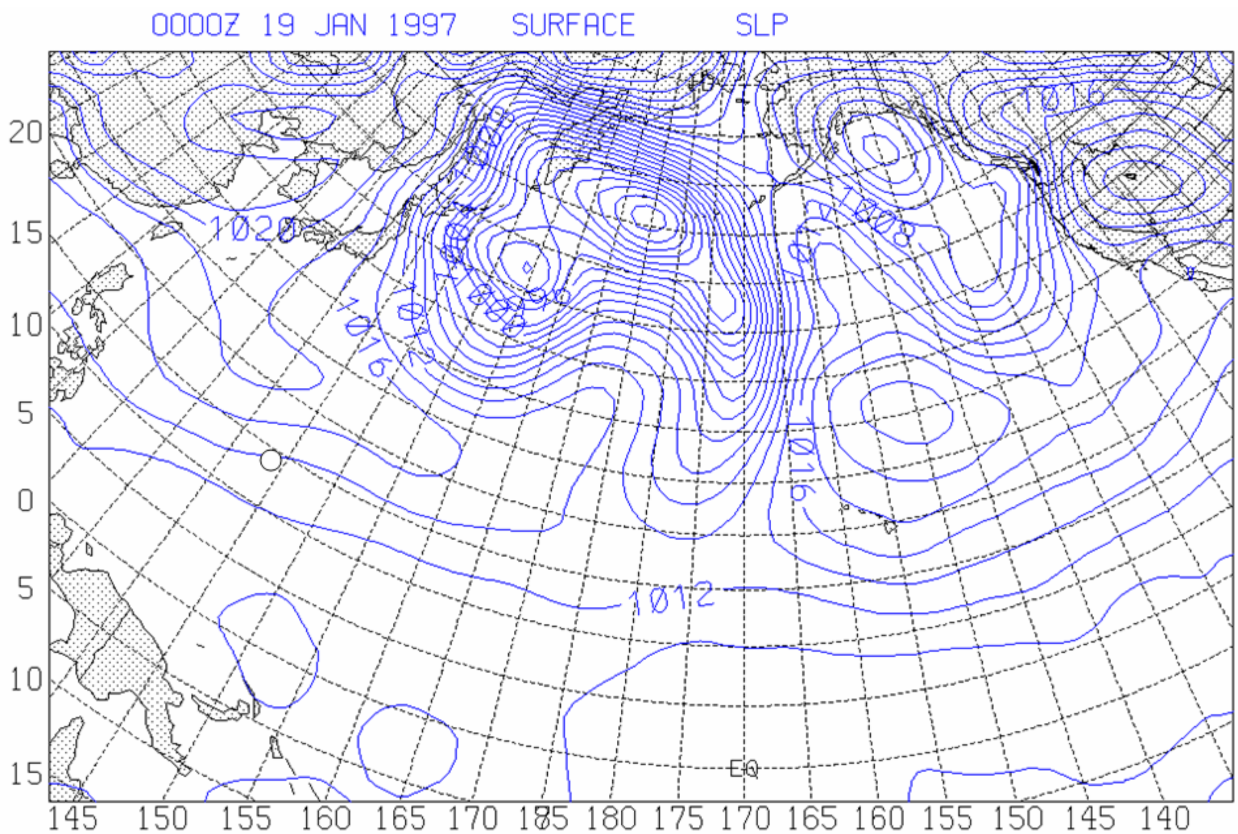

Figure 46. Sea level pressure pattern for 19 January 1997 resembling 25 knot climatology

Figure 47 is the cross section over Guam for 19 January 1997 and resembles the 25-knot climatology as well. Geostrophic flow was 13 m s^{-1} suggesting a slightly weaker gradient when compared to the other cases. The low static stability and stronger winds suggest wind gusts of 25 knots should occur but as noted earlier, the winds gusted to 23 but not 25. Again, subtle, local factors may have contributed to preventing 25 knot wind gusts on this day, even though the large scales favor them.

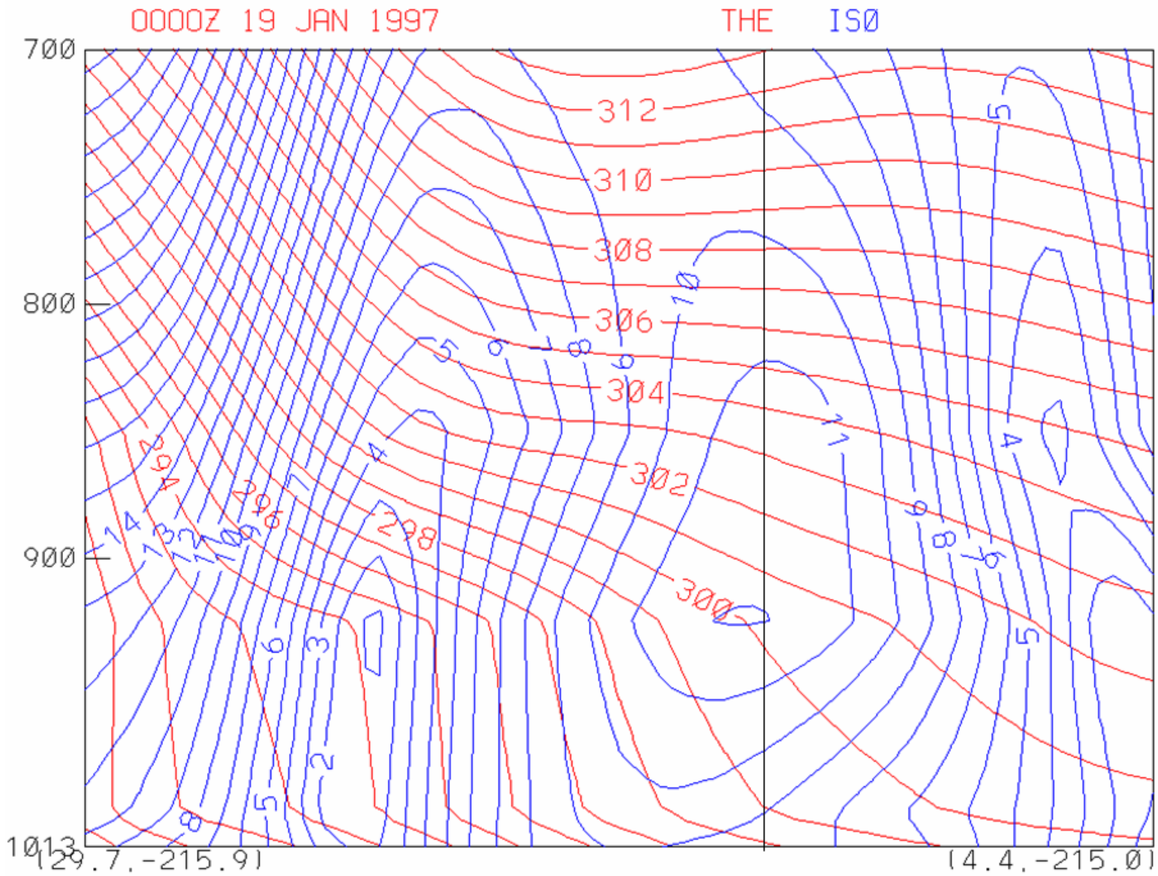

Figure 47. Cross section over Guam for 19 January 1997

c. 15 July 2006

The following case is a “No Hit” false alarm case in which the 17 OWS issued a wind advisory but the winds never exceed 25 knots. Figure 48 is the sea level pressure pattern near Guam for this case which resembles 15-24 knot climatology for Guam, especially with the weak pressure gradient over Guam. The extension of the subtropical high from the east is clearly seen but low pressure, a developing tropical system, to the south is present which of course is not represented in the average. In the absence of any rain showers, the winds stayed below 12 knots the entire day.

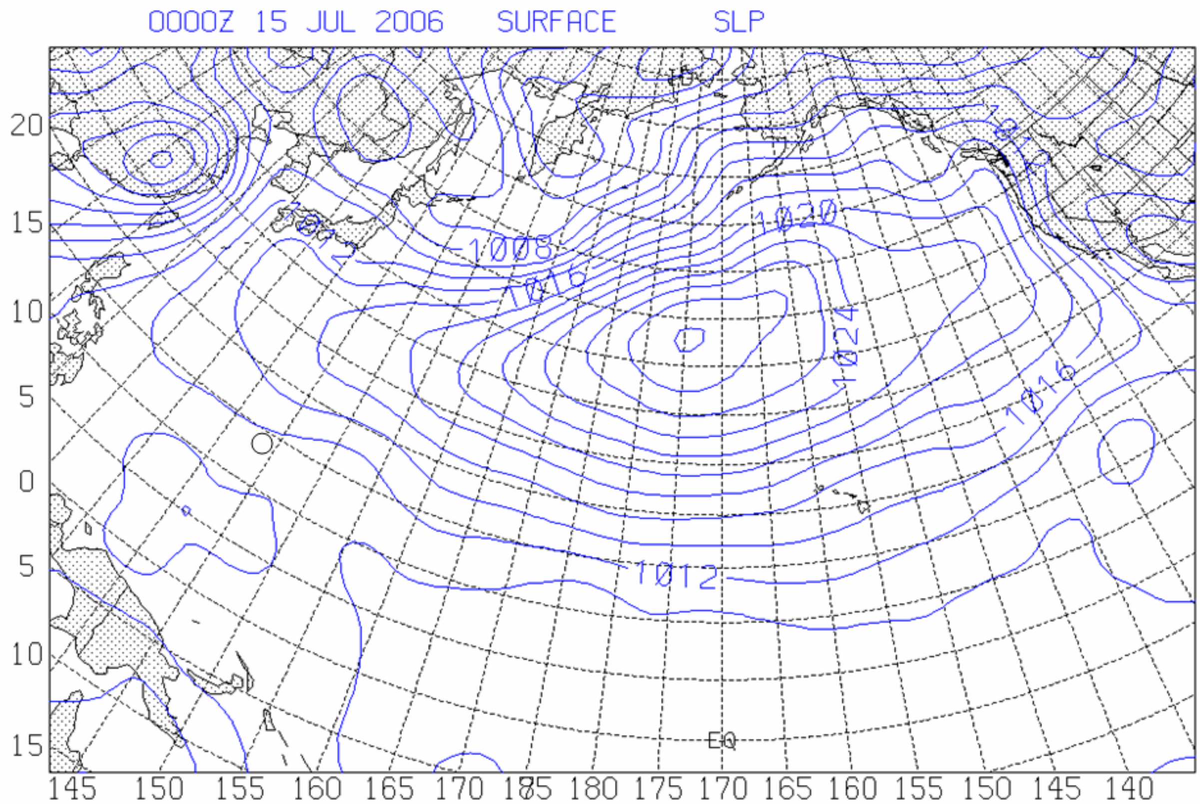

Figure 48. Sea level pressure pattern near Guam for 00 UTC 15 July 2006 resembling the 15-24 knot average

The cross section for this day (Figure 49) shows that high static stability in the boundary layer exists and exceeds that of climatology. The winds are fairly light in the vicinity of Guam, at just 5-6 m s^{-1}; however the geostrophic flow is 13 m s^{-1}, similar to the previous "no hit" case. This false alarm case is a good example of how these climatologies can highlight critical synoptic scale aspects to separate 15-24 and 25-knot days. This suggests its potential use as a forecast tool.

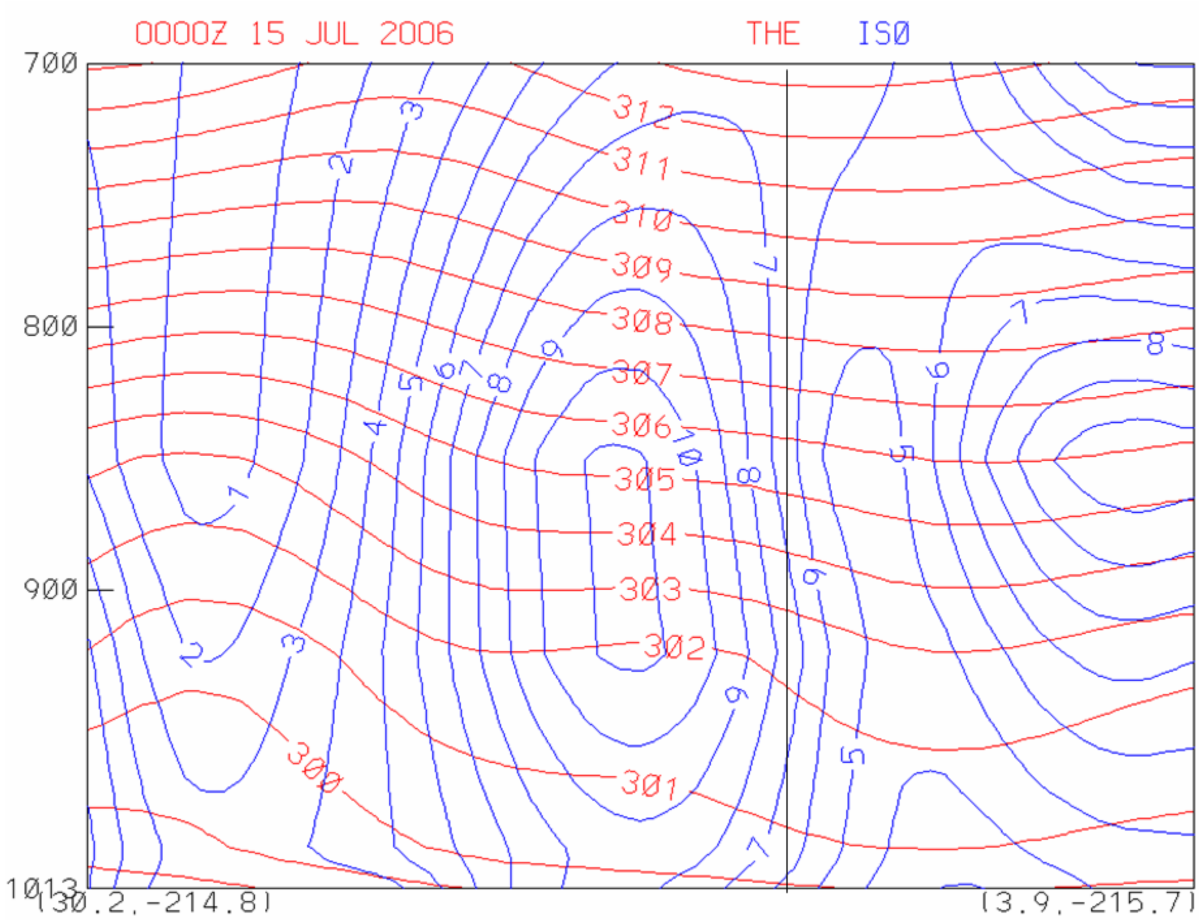

Figure 49. Cross section over Guam for 00 UTC 15 July 2006 resembling the 15-24 knot average

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

In this study, the forcing of 25-knot winds at Hickam AFB and Andersen AFB was investigated in an attempt to locate an identifiable signal to aid in the forecasting of these conditions. Both locations exist in the subtropics of the Pacific Ocean in which trade winds are the predominate weather feature. Gusty winds are the norm in these areas and the possibility of crossing the 25-knot threshold can be an almost daily occurrence. Ten years of surface observation data were collected for both locations and analyzed. Days in which weather such, as rain showers or thunderstorms, were eliminated in order to isolate those days where true trade wind gust events occurred. Of the ten years of data, 258 were days in which Hickam AFB experienced wind gusts of 25 knots or greater and 1,077 were days in which winds between 15 and 24 knots occurred. Andersen experienced 99 days of wind gusts 25 knots or greater and 448 in which the winds gusted between 15 and 24 knots. These days were then composited in order to find the average conditions occurring on these days. The results of the study are summarized below.

Two separate climatological regimes arise from the compositing of the separate days. For Hickam, the average conditions for days that gusted to 25 knots or greater is noticeably different than those that didn't. Sea level pressure charts show distinct location differences in the subtropical high north of Hawaii. On days in which the winds gusted to 25 knots or greater, the subtropical high center was located almost due north of Hawaii placing the islands well outside of the 300-500 mile zone identified by previous studies as the strong trade wind zone. The strength of the subtropical high was just over 1024 mb with Hickam AFB falling between the 1018 and 1016 mb contours. For days less than 25 knots, the center of the high is much further east, by roughly 10°. Its strength is just over 1022 mb and the gradient over Hickam has weakened, although still between the 1018 and 1016 mb contours.

Cross sectional analyses across Hawaii near Hickam for both regimes identified critical differences in boundary layer characteristics. The 25-knot days were characterized by low static stability in the lower layers and overall stronger flow. The

average wind speeds were 10-11 m s^{-1} indicating that stronger winds associated with the position of the high and tighter gradient were able to mix to the surface and cause 25 knot or greater wind gusts. Days that stayed between 15 and 24 knots were characterized by higher static stability and lower wind speeds.

Similar differences in climatology were noted for Andersen AFB as well. On those days where the winds gusted to 25 knots or greater, climatology shows an extension of the Siberian High protruded out and over the Pacific north and east of Guam with a strength of about 1018 mb. On days that did not reach the 25-knot threshold, the extension of the Siberian High was not present as it had receded back towards Asia. The gradient is weaker and a large low pressure system exists north east of Japan.

Cross sectional analyses over Guam was also similar with those of Hickam. 25-knots or greater days were characterized by low static stability and stronger flow. Days that did not gust to 25 knots had higher static stability and less flow.

Therefore, according to the climatological average, a stronger high and its position closer to the islands will produce stronger winds. This is true for the majority of cases that were reviewed; however, as seen in the presented cases that this is not true for every instance. Other factors play into whether or not winds exceed 25 knots such as stability. Each location had instances where the sea level pressure pattern resembled climatology for one case but the opposite occurred. In most instances a cross sectional analysis would reveal the reasons why. If a gust to 25 knots occurred, it was usually because of low static stability and stronger flow. If the winds did not reach 25 knots, higher static stability and weaker flow could be found. A few cases; however, indicate this will not always happen. In particular, the 19 January 1997 case for Guam. The sea level pressure pattern and cross sectional analysis both point to the occurrence of 25 knot winds and although very close, 23 knots, it did not occur. Cases of this nature were few however as the vase majority of cases fell in line with climatology.

Diurnal forcing was evident as expected in that the strongest stability for both locations was in the morning and then decreased as the afternoon approached. The wind gusts occurring within hours of 00 UTC for Hickam and 06 UTC for Andersen suggested decreased stability around this time although wind gusts at Andersen frequently occurred

at all hours. Upon analysis however, a diurnal stability change on average was present for the 25-knot climatology and only slightly for the 15-24 knot climatology. These stability changes were evident in most cases, but not always.

Overall, climatology does show that there is a relationship between the strength and location of the High and the static stability over the islands. As the high intensifies and moves closer to the 25-knot climatology, one should look for stability changes that may lead to the occurrence of 25 knot wind gusts. By identifying which climatological regime the islands fall into, static stability changes as the day progresses, and the strength of the flow nearby, an improved forecast for greater than or less than 25 knots may be achieved.

B. RECOMMENDATIONS

This study determined the climatological average weather conditions over the Pacific for days in which the winds gusted to 25 knots or more as well as those days in which the winds were 15-24 knots at Hickam and Andersen AFB. Although individual synoptic scale weather systems will differ from climatology, identifying which regime the current conditions fall under is the first step in accurately forecasting wind gusts. This study is only the first steps in understanding the forcing of 25 knot winds for both locations. It is recommended that this remain on the Air Force Weather topics list to further study topographical effects, detailed boundary layer characteristics, and Mesoscale events that may contribute to 25-knot wind gusts.

The emphasis of this study was on strict trade wind flow. Days in which weather such as rain showers of thunderstorms occurred were not included in this study. As indicted by the 17OWS, weather presents a major problem for 25-knot wind forecasts for Andersen AFB. Observations have shown that the winds may be 10-15 knots the entire day at Andersen and one rain shower may cause the winds to gust above 25 knots without warning. This falls outside of the realm of strong trade wind flow and seems to be more of a downburst issue. It is recommended this be added to the Air Force Weather topics list.

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